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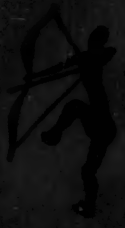

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a record of research

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HUMAN BIOLOGY
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FORENSIC ANTHROPOLOGY IN GERMANY

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IN January, 1953, while the author was awaiting her visa in the U. S. Consulate at Frankfurt, she read in an American magazine a story concerning the daughter of a Mrs. M. from Chicago who had been kidnapped when she was two years old. Since that time she had been sought by her mother. Twenty-two years later, through the help of some newspapers, a young woman was found in California who might possibly be the lost child. She was brought to Chicago, and two photographs show how the head and face of the mother and the presumptive daughter were measured. However, only a few newsmen were impressed by such methods. The young woman returned to California, and Mrs. M. shut the door finally to reporters.

In Germany, a number of such cases have been worked on by anthropologists and human geneticists in recent years. Many families were separated at the end of the war by the Soviet invasion, by the flight of the population from Eastern Germany, and by the disorder in the bombed cities. Often the names and data of little children were lost and, by the time the mother or the parents could find them, the children

themselves had changed by growing up. Then government officials sent the family to an anthropological or genetic institute which could often give them the assurance that the displaced child really belonged to this family (Schwidetzky '49, Steffens '50).

However, such cases are but a very small part of the work of such institutes. Much more frequent are the cases of illegitimate children whose progenitors refuse to pay for them and similar forensic cases where the courts request expert opinion from anthropologists. The German Anthropological Society (Deutsche Gesellschaft für Anthropologie) has published a list of experts fully qualified both by training and experience; the latest edition (1952) contains the names of 35 anthropologists and human geneticists, some of whom are physicians, the others biologists. Some of these experts have established private laboratories of forensic anthropology, while others are connected with university institutes where younger anthropologists, whose salaries are paid for out of the fees charged, take part in the investigations. On the average, each expert on the approved list may take on about 75 cases per year. Thus about 2500 expert opinions are presented to the courts by anthropologists every year. More opinions are given by physicians who are not on the list of the German Anthropological Society because they have neither the education nor the experience necessary for fully qualified investigations. These are not blood-group determinations. Cases are sent to the anthropologists only when the blood groups, determined by institutes of serology, legal medicine, etc., have led to no definite conclusion, that is to say, the presumptive father could not be excluded.

The first anthropological opinion of this kind was given in the year 1926 by Professor Otto Reche who was at that time the director of the Anthropological Institute at Vienna. In the next decade the anthropological institutes, particularly at Berlin (Eugen Fischer, von Verschuer, et al.) and at Vienna (Weninger, Geyer, et al.), continued to develop the method. Other institutes participated in this work, collected and exchanged experiences, and trained younger human biologists. The courts came increasingly to trust in the new method which had helped to clear up so many cases. In 1931, the Supreme Court of Vienna decided for the first time that the non-admittance of an anthropological expert opinion was a defect in legal proceedings, and soon this was the general point of view in Germany as well (Harrasser '35, '50).

According to a recent inquiry in various countries, Germany and Austria are ahead not only in the development but also in the applica-

tion of the methods of forensic anthropology (Schwidetzky '51a). Only in Sweden and Denmark are they also well introduced into the administration of justice, but there are not so many referrals as in Germany. The Institute of Human Genetics and Race Biology at Uppsala, whose director is Professor G. Dahlberg, seems to have the only department of forensic anthropology in Sweden, and it renders about 25 to 30 expert opinions each year. In Czechoslovakia, German experts introduced the method during the occupation of that country, and a Czech anthropologist has continued to use it after the war (Valšik '49). In Poland and Switzerland as well the first opinions have been prepared by anthropologists (Pfannenstiel '53). In the United States, and in many other countries too, the method is almost entirely unknown. Sometimes physical anthropologists are requested to render an opinion in cases of supposed Negro descent, as, for example, when a child is to be adopted. But this is really more a matter of racial diagnosis than one of family descent, since only the child and not the parents is examined. In answer to the inquiry mentioned above (Schwidetzky '51a), an American geneticist wrote as follows: "I am amazed at the degree to which both anthropologists and the legal profession in Western Germany have developed the scientific aspect of the determination of paternity. I believe that is far ahead of anything done in this country."

After the war there was an immense increase in the number of referrals in Western Germany: many illegitimate children were born, many former soldiers when they returned home were confronted with offspring in their families whose progenitors they could not be or they believed themselves not to be. In recent years the number of cases has become more normal and in a better proportion to the number of available experts. And as scientific research revived in Germany, the further development of forensic anthropology took place. In its Mainz meeting in 1950, the German Anthropological Society devoted an entire day to lectures and discussions on this topic. In 1953, a special meeting for experts was held in Münster, arranged by the Institute of Human Genetics, which is now the most active center of research in human genetics in Germany. Its director, Professor von Verschuer, is the president of the German Anthropological Society at the present time. These special meetings of forensic anthropologists will be held every two years to exchange experiences and to discuss the results of continuing scientific research.

The method of determining paternity involves many hereditary traits

with the exception of blood groups which are determined in advance. Some of these traits with simple inheritance, such as eye color, hair form, or the ability to taste P.T.C., provide evidence to exclude the wrong father under some circumstances, but not with the same degree of certainty as is the case with blood groups. However, the principal part of the method consists in the comparison of the child, mother, and suspected progenitor(s) in a large number of complex polymeric traits whose hereditary nature has been established by twin and family research work but whose mode of inheritance is not known in detail (Kramp '39, '40, '42, '48, Loeffler '40). The greater the number of similarities between the child and the progenitor in question, the more probable it is that he is really the child's father. Thus it may be possible to determine the father positively (Vaterschaftsnachweis), while on the other hand by stating that blood groups and other monomeric characters we can exclude a suspected progenitor from being the father (Vaterschaftsausschluss).

In order to determine the total resemblance in hereditary traits it is recommended to consider as many of them as possible. In the " Instructions of the German Anthropological Society for Anthropological-Genetic Expert Opinions in Forensic Cases " (1949) 4 pages are devoted to the enumeration of hereditary traits which must be examined. These include the following groups: structure of the iris (including eye color), hair texture and hair growth patterns, form of the head (including the forehead), total face, eyes (including eyebrows, eye lashes, eye folds), nose (including nostrils and nasal wings), mouth and chin, ear, oral cavity (including teeth and tongue), hands and feet, papillary ridges on fingers, palms, toes, and soles), and physiological traits such as the ability to taste P.T.C. Photographs, at least of the head as seen from the front and from the side, must be taken and added to the expert opinion. Special photographs of the iris, ears, eye region, nose from below, hands, and feet are recommended, especially when there are important similarities between the child and the presumptive father.

It is obvious that not all of these traits have the same value in every case:

1. Traits which change greatly during growth, such as the form of the forehead, nose breadth or chin, are less important, but they must always be examined because there may be striking similarities.

2. Sex variability has also to be considered since the child is always

compared with individuals of both sexes, i. e. mother and presumptive father.

3. Those traits which are similar in the child and mother are less important for the comparison between the child and presumptive father. But they are not entirely a matter of indifference: if the child resembles the mother and the presumptive father, this is a more positive piece of evidence than when the child is similar to the mother and dissimilar to the presumptive father.

4. Similarity in traits of frequent occurrence do not lend the same evidence as do rarer traits.

5. Of course, such highly modifiable traits as body weight or chest circumference are of lesser importance.

Experience is needed to consider all these points of view, to know the variability by age and sex, the approximate frequency of the traits, the possible effects of environment and so forth. Therefore, the German Anthropological Society admits to its list only human biologists who have had three years of experience in an appropriate institute, and three expert opinions of each applicant are examined by a commission of 5 experts. An attempt is also made to clarify those cases in which two expert opinions are given whose results do not correspond. It may be mentioned that there have been but few cases of this kind where both experts have been admitted to the approved list of the Society.

It is obvious that the methods of determining paternity have not yet been exhausted. There are several avenues for future development: 1. New hereditary traits are being sought for. 2. An attempt is being made to determine more prescisely the variability and frequency of the hereditary traits already known, thereby providing further evidence of special similarities. 3. Methods for the more precise summarization of the detailed findings are now under examination.

1. New hereditary characters are being sought for: though twin research has examined an immense number of morphological traits, some of them may have been overlooked or can be rediscovered for the purposes of forensic anthropology. Klenke ('51) examined the details of the palate from this point of view: the palatal ridges, the form of the *rapha mediana* and the *papilla incisiva*, the height and form of the palate can be used. Schäfer ('52) studied the uvula, Biegert ('53), the tongue Schwidetzky has settled the hereditary character of certain morphological variations of the skull such as the *crista supramastoidea, torus* or *sulcus*

bregmaticus, depressio lambdoidea and the *tubera parietalia.* Most impressive are the studies of Loeffler ('53) on the hair-streams of the forehead and neck. Rieger and Thums ('51) proposed an ophthalmological examination which has already given evidence in some paternity cases. This leads to pathological traits which sometimes clear up or decide a case.

Last but not least, the vertebral column may be mentioned here. It has been vehemently discussed in recent years. Kühne has assumed that the variations of the spine are determined by one pair of genes. There is a cranial and a caudal tendency in variations, and the caudal one is said to be dominant. Special expert opinions based on the spinal column (Wirbelsäulengutachten) were made by Kühne and other experts in paternity cases, especially during the years 1948-1950 (Bickenbach '47, Kühne '50). Variations in the spinal column were employed as excluding traits like blood groups, but some experts have also pointed to the positive similarities between parents and children (Illchmann-Christ and Diethelm '53, Pratje '51). Lenz ('51a, '51b) rigorously criticized this method at the 1950 meeting of the German Anthropological Society, and it has since almost completely disappeared from the practice of forensic anthropology. The results of further research should be awaited. In the meantime, one paper has been published, and perhaps this is the beginning of a revindication of the trait (Illchmann-Christ and Diethelm '53). In 113 paternity cases investigated by Lehmann, variations in the spinal column were examined independently by Illchmann-Christ and Diethelm. Only in one case was there a certain contradiction between the two results, and the authors have also pointed to the positive similarities between the children and their parents. To be sure, such investigations are expensive, since 4 or more X-rays of the spine are needed. But in important cases which cannot otherwise be sufficiently cleared up they may give supplementary evidence to the courts.

In regard to Mendelian inheritance, the experience of forensic anthropologists has disqualified another trait as well: the Bonnevie formulae for digital ridges. The average number of ridges, the maximum and minimum and the differences between single fingers show similarities between relatives, but the trait cannot exclude a presumptive father, as the formulae pretend to do (Baitsch '53). There are too many discrepancies even between children and mothers which cannot be solved. At their Münster meeting, therefore, the anthropologists decided to no longer use the formula in their expert opinions.

2. An attempt has been made to determine more precisely the variability and frequency of the hereditary traits already known. This is a most important part of the research and probably most work is being done in this field.

The papers of Ehrhardt ('51) on the eye folds and those of Pfannenstiel ('52) on the traits of the mouth and chin will be mentioned first of all. They give the frequency of the traits by age groups. It is supposed, and this really seems to be quite certain, that they point to a frequent trend in individual development, but not all possibilities of individual changes by growth and age can be determined in this way. Examinations of the same individuals at different ages have to be carried out. This research has been started at the Institute of Human Genetics at Münster. Professor von Verschuer studied the same pairs of twins in 1924-25 and in 1950. The children of the first studies have now become adult, and the adults are now in old age. In this small but extremely valuable study the age changes in physiognomical features can be compared with the non-hereditary differences between monozygotic twins. The first paper (Gerhardt '52) already has verified very clearly the general experience of anthropological experts that the classification of morphological traits in terms of a pre-determined scheme is not sufficient. In the Instructions of the German Anthropological Society we find the following statement:

> "By wedding oneself to a pre-determined scheme, one's glance is diverted from that which is essential, that is to say, the critical examination by *comparison*. In this latter case it is basically a question of the finer details of certain structures, of the *degree* of similarity and dissimilarity, which are to be observed in the distinguishing traits. Such observations cannot be forced into the framework of an already existing measurement blank but must be carefully noted in each individual case by a detailed description of form."

Beyond the precise verification of this experience, the twin studies show which different forms can be considered as similar from the genetic point of view. The same question is to be put to traits without considerable age changes. Much work in Germany is being done on the papillary ridges which are of such great importance in modern human biology. According to Kramp ('52) and to our general experience as well, similarity in special details are more important in paternity cases

than conformity to pattern-type. Different patterns can have similar detailed traits, and the same type of pattern in the child and presumptive father provides less evidence when the special structures are highly different. In the same way, the intrafamiliar variability of palm ridges was studied by Ehrhardt ('53), that of the *planta* by Gieseler ('53). But also quantitative traits, such as the number of whorls or the height-breadth index of finger-patterns studied by Becker ('53) should not be completely neglected. In such traits similarity or dissimilarity can be determined only by statistical methods, and it is, therefore, particularly important to know their variability and frequency.

The same is true for anthropometry. Most experts take only certain measures and then only because of anthropological tradition. Keiter ('51a) has pleaded, however, for a rehabilitation of anthropometry and has developed an "anthropometrical diagnosis of descent" (anthropometrische Abstammungsdiagnostik) with approximately 50 anthropometrical traits. This diagnostic method of Keiter has been often criticized and rejected. In fact, however, an exact analysis of anthropometric data can give some evidence, as Schwidetzky verified for head measurements at the Münster meeting, and it is able to complete morphological comparison. Children and adults can well be compared when the deviations from the average of age and sex groups are taken into account: especially great deviations, similar in both the child and the presumptive father, can assist in determining the biological relationship.

3. Methods are being examined for the more precise summary of the detailed findings. The main trend in the development of forensic anthropology is the growing complication of the examinations. More and more traits are introduced, and, in general, the more recently introduced traits are the more difficult in method: it is easy to take finger-prints but more difficult to take toe-prints, as recommended by the Society's Instructions and now adopted by nearly all experts; the examination of the palate needs a plaster-cast; that of the iris, a special magnifier; Loeffler's hair-streams, a movable lamp (and, unfortunately, a good deal of time); the spinal column has to be X-rayed. Technical assistants may help during the morphological examinations, for instance in taking finger prints and photographs. The main part of the examination, however, must be done by the expert himself. The direct morphological comparison of child, mother and presumptive father, and the summary of the ever-increasing number of details in the final result

cannot be left to assistants. Therefore, the method cannot be too much mechanized and reduced to merely a technical procedure, and more and more experience and time are needed to prepare a fully qualified expert opinion.

As more and more details have to be summarized, it becomes increasingly important how the final result is obtained. In this respect, the existing Instructions of the Society (1949) are rather indefinite. According to these Instructions, all details have to be summarized in one of the degrees on a scale of probabilities as follows:

1. The probability that the presumptive progenitor is the real father borders on certainty;
2. It is highly probable that the presumptive progenitor is the real father;
3. It is probable that the presumptive progenitor is the real father;
4. It is impossible to reach any conclusions;
5. It is improbable that the presumptive progenitor is the real father;
6. It is highly improbable that the presumptive progenitor is the real father;
7. It is obviously impossible that the presumptive progenitor is the real father.

Lenz prefers other terms, and other experts are following his lead:

1. It is evident that the presumptive progenitor is the real father;
2. It is reasonable to suppose that the presumptive progenitor is the real father;
3. It is not evidently impossible that the presumptive progenitor is the real father;
4. It is reasonable to suppose that the presumptive progenitor is not the real father;
5. The presumptive progenitor is evidently not the real father;
6. It is evidently impossible that the presumptive progenitor is the real father.

These terms are perhaps more convenient for the judges, who are not accustomed to the theory and terms of probability.

In a modification of Loeffler's scheme (Loeffler '40), which employs

additional categories, these degrees of probability might be equated to the following statistical probabilities:

1 = > 99
2 = 91–99
3 = 66–90
4 = 35–65
5 = 10–34
6 = 9–1
7 = < 1.

But that is only one approach, and there is no exact basis for these equations. It is only a matter of practical experience just how the final result is to be classified. Even a verbal definition of the various degrees is lacking in the Society's Instructions. Schwidetzky ('51b) has attempted to do this by equating the degrees of the final result with the degrees of total resemblance, which is, in fact, the main basis of the summary:

Similarity — 3 = *Evidently impossible* in forensic cases. Though there are many deviations from the mother, the dissimilarities with the presumptive father exceed greatly the similarities. There are also striking discrepancies in traits whose mode of inheritance is well known or only approximately known.

Similarity — 2 = *Very improbable* in forensic cases. There are many and considerable differences between the child and the mother, but also more dissimilarities than similarities with the presumptive father. The similarities between the child and the presumptive father do not involve rare and striking traits.

Similarity — 1 = *Improbable* in forensic cases. There are more dissimilarities than similarities between the child and the presumptive father in traits differing from the mother, but the deviations from the mother are small and involve no traits whose mode of inheritance is known.

Similarity 0 = *No evidence* in forensic cases. The traits of the child which differ from those of the mother are partly to be found in the presumptive father. All

similarities involve frequent traits, but also the dissimilarities are not striking, since the deviations from the mother are small.

Similarity + 1 = *Probable* in forensic cases. There are more similarities than dissimilarities between the child and the presumptive father in the traits differing from the mother, but most similarities involve frequent traits.

Similarity + 2 = *Very probable* in forensic cases. Some of the similarities between the child and the presumptive father differing from the mother are striking, that is to say, they involve rare details or the similar structure of whole morphological regions.

Similarity + 3 = *Evident* in forensic cases. There are still more striking similarities between the child and the presumtpive father; the child resembles more the presumptive father than the mother.

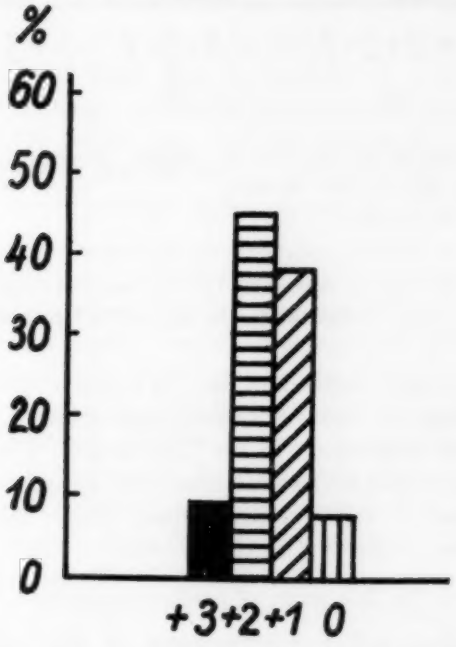

FIG. 1. Distribution of the degrees of total similarity between children and father in unquestionable families (100) children).

Note that the degree " 0 " is also represented in unquestionable families.

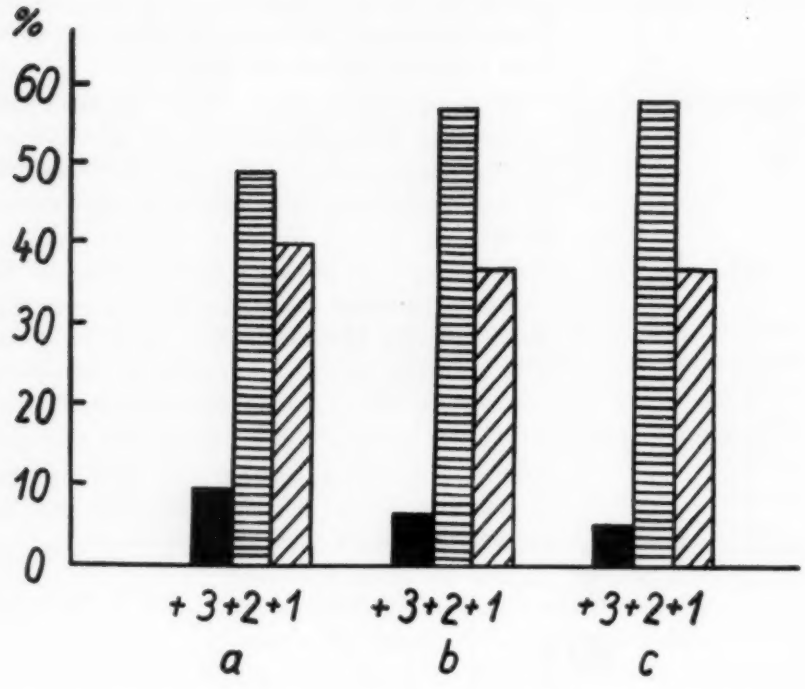

FIG. 2. Distribution of the positive degrees of total similarity between between children and "right" fathers.

(a) In families.

(b) In forensic cases with one presumptive progenitor.

(c) In forensic cases with two presumptive progenitors.

Note the similarity of distribution in families and forensic cases.

But these are vague definitions too. It is one of the most vehemently discussed problems of forensic anthropology whether it is possible to give a statistical formulation to the final result. The first method of this kind was developed by Essen-Möller ('38, Essen-Möller and Quensel '39) and applied by Geyer ('38). Essen-Möller calculates for each trait a "Critical Value" (Kritischer Wert) which may be defined as $\frac{Y}{X}$, where X is the frequency of conformity between the children and the "right" father and Y the frequency of the trait in the average population or in the "wrong" fathers. The probability of finding the "right" father by this trait is then

$$P_r = \frac{1}{1 + \frac{Y}{X}} \tag{1}$$

The probability of finding the "right" father by several traits (1, 2, 3, etc.) is

$$P_r = \frac{1}{1 + \frac{Y_1}{X_1} \cdot \frac{Y_2}{X_2} \cdot \frac{Y_3}{X_3} \cdot \cdots} \tag{2}$$

When there are two presumptive father (*I, II*), of whom one is the real progenitor, there is a greater probability of finding him, that is to say, the probability is higher than for a single man.

$$P_{r_I} = \frac{(\frac{Y}{X})_{II}}{(\frac{Y}{X})_I + (\frac{Y}{X})_{II}}. \tag{3}$$

To this several serious objections have been made (Ludwig '51, Weninger '49). The two most important ones may be mentioned.

1. The "critical values" are multiplied in formula (2). This would be valid only if there were no correlation between the traits. But even if the correlations between all the traits considered in paternity cases were known (up to now they are not), it is practically impossible to account for them in the formula. Thus, the calculation has to restrict itself to non-correlated traits, foregoing many other traits, possibly important ones.

2. The "probabilities" of the Essen-Möller formula are not real statistical probabilities, since they do not consider the statistical error.

Keiter ('53b) has replied to these arguments that Scheidt had calculated hundreds of correlations between morphological traits of the face and had found but few correlations of a low degree. Wichmann ('51) used a much greater number of traits than formerly customary and could quite well separate the "right" from the "wrong" fathers, as determined in 120 paternity cases by morphological comparison.

Further methods have been proposed or examined. Keiter ('51a, b, '53a) has developed two statistical methods.

1. The diagnosis of descent by correlations (Korrelationsstatistische Abstammungsdiagnostik). It is applicable only to quantitative characters, but also many morphological traits can be quantified (high-low,

big-small, etc.). Keiter always takes 7 degrees. The correlation between the child and the presumptive father is calculated for each case, and the variability of correlation-indices is determined. There is some over-

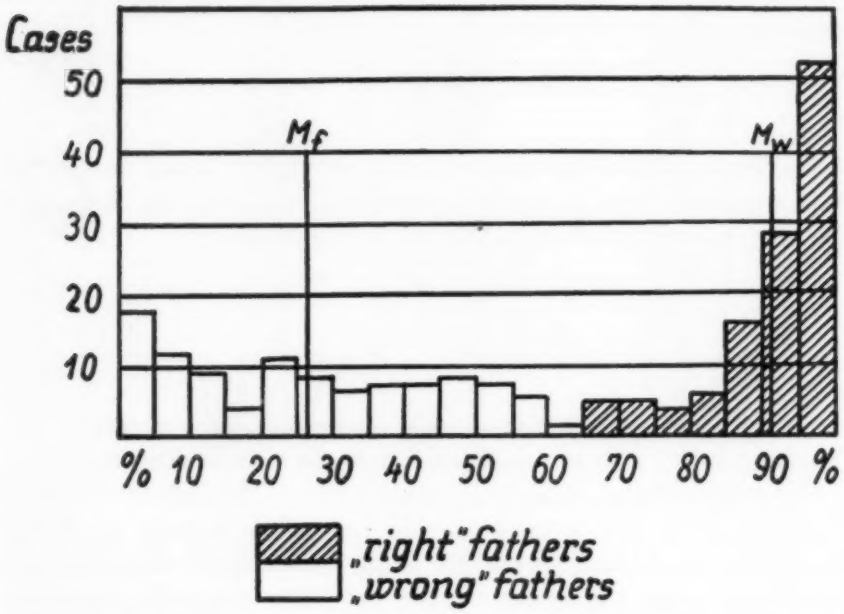

FIG. 3a. The distribution of the degrees of probabilities according to the 2nd Essen-Möller formula. (216 presumptive fathers in 120 forensic cases, 31 traits). "Right" and "wrong" fathers are determined by total morphological comparison. Note that there is no overlapping of the distributions in these 120 cases. However, as the distributions are contiguous, an overlapping may occur in other cases. There are also probabilities > 50 for "wrong" fathers, but no probabilities < 50 for "right" fathers.

M_w = Average of the "right" fathers.
M_f = Average of the "wrong" fathers. (after Wichmann)

lapping between "right" and "wrong" fathers determined independently by morphological comparison, but the difference between the two groups is quite clear.

2. The "Logarithm of Paternity" (Vaterschaftslogarithmus) determines for each trait the similarity between the child and the presumptive father on a 7-point scale, at the same time taking the similarities between the child and the mother into account. The different combinations are

classified according to their value as evidence (Keiter '51b). Ludwig ('51) has proposed the use of discriminant functions to separate " right " from " wrong " fathers. This method can also be applied only to quan-

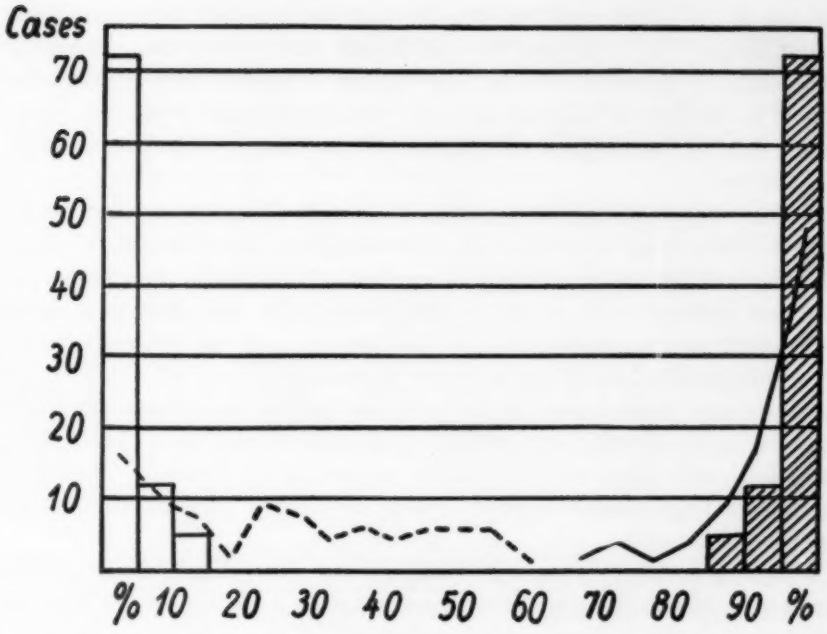

FIG. 3b. The distribution of the degrees of probability according to the 3rd Essen-Möller formula. (Two presumptive fathers of whom one is the real progenitor).

Note that the distributions are now well separated.

There is no overlapping and contiguity.

——— Distribution of the " right " fathers.

– – – – – Distribution of the " wrong " fathers according to Fig. 3a.

(after Wichmann)

titative traits of normal distribution. Apparently no one has yet attempted to use it. Schwidetzky ('53) has used a coefficient of likeness, and it is one of the main purposes of her family investigations (Schwidetzky '51b) to define more exactly the " total resemblance " and its variability in families in which it may reasonably be assumed that the fathers are in fact the real progenitors. Only family research can really prove or disprove the validity of statistical methods of sum-

marizing. When they are applied to "right" and "wrong" fathers in paternity cases, there may be a selection of "good" cases, that is to say, those which could be well decided. But there is always a number of undecided cases (approximately 10%) whose presumptive progenitors cannot be classified either as "right" or as "wrong" fathers. Total resemblance "0" between the child and the father also occurs in unquestioned families. Thus only family research can indicate the whole variability of total resemblance between relatives and thus define more exactly the degrees of probability in determining the "right" progenitor.

Most experts refuse to use statistical methods in the opinion itself. There was a long discussion on this subject at the Münster meeting. It was pointed out that only a portion of the traits considered in forensic anthropology can be proved statistically and that it is more important to *see* similarities and differences than to *calculate* them. A rigid classification of traits which is inevitably involved in statistical analysis may indeed conceal the real similarities, and there are often morphological details and special structures which have never been described and which are too rare to be studied statistically. But it is just such traits and structures which are of the greatest importance in paternity cases.

This is certainly true. Perhaps, on the other hand, some experts are too hostile to the use of statistical methods in regard to the practice of forensic anthropology. Some arguments in their favor may be mentioned here.

1. General conclusions and a theory of the method of similarity are impossible without statistical analysis, and, of course, general results are also of use in the practice of forensic anthropology. For example, statistics has verified the practical experience that expert opinions are somewhat more positive for boys than for girls and that there is no important difference in certainty for children of three years and for those older than three; increased difficulties exist only for younger children, partly on account of their undeveloped traits, partly on account of technical difficulties in taking finger-prints, plaster-casts, standardized photographs, taste tests, etc. There is also a similarity among the various lovers of the same woman, and it has been proved that the analysis of similarity is more successful in determining positively the "right" fathers than in excluding the "wrong" (Keiter '53a, Schwidetzky '51b).

2. Statistics help in establishing more exactly similarities and dissimilarities, especially in quantitative traits. It is true that statistics require a precise classification of traits which do not suit completely the practical purpose of the method. But a large number of traits are well adapted to statistical analysis, such as measures and indices, or the present-absent traits which are not too rare in the average population. Many details can be settled more precisely, and even further details may be discovered by statistics. Certainly no expert would reject statistics for the critical investigation of single traits, although heretofore it has been possible only for a few of them.

3. There is a general trend in the natural sciences (and last but not least in genetics) to quantify their methods, and if statistics are admitted to the exact analysis of single traits, it is impossible to prevent their application to the summary of details.

It is true that none of the present statistical methods are fully satisfactory. Only a portion of the comparison of children and parents is involved. Such methods do not consider the similarities between the child and the mother, or they are unable to treat quantitative traits simultaneously with pure descriptions of form. They cannot see the wholeness of individual structures, being only able to sum up certain details in a mechanical fashion. I believe that it will be forever impossible to cover by statistical summaries all the details which are now used in forensic anthropology. There will be a better approach only with the further development of methods. But that portion of the results which can be expressed in an exact manner (in the sense of mathematics) should not be expressed inexactly. Perhaps at some time in the future there will be sufficiently exact proofs to decide most cases. Of course, the eye, the "morphological glance" can never be dispensed with, because the traits have first to be determined and classified before statistical analysis can proceed.

Today, about 10 per cent of the paternity cases remain undecided. The aim of the method of determining paternity must be that all cases can be cleared up and that the share of the high probabilities will become greater and greater. Indeed, the highest degree of probability is not necessary for the judge in all cases; often the mere presence of some positive or negative evidence suffices. However, for the experts it is much more satisfying to have full certainty. But already today one can say that "*pater semper incertus*" is no longer true.

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THE DEPOPULATION OF YAP

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IN much of the world, the spread of modern civilization has brought about the assimilation, depopulation or extermination of many small non-literate societies. Foreign diseases have become rampant among these peoples, along with wars, apathy and disorganization.

One such depopulation has gone on for perhaps a century on Yap, in western Micronesia. Yap is a cluster of hilly islands with a total area of 38.67 square miles, all enclosed within a single coral reef. Its inhabitants are typical of the high islanders of the central Pacific in that they eat mainly root crops from their gardens and fish and shellfish from the sea. Their social organization strongly emphasizes rank, with elaborate protocol and restrictions on the intermarriage and interdining of persons of high and low degree (Schneider, '53). Among the objects most treasured by the Yapese is their famous "stone money." This rich and intricate culture is still remarkably well preserved by a society of only a fraction of its former numbers.

The living islanders say that the depopulation followed a period of overpopulation which we consider to have occurred before 1850. Yap was then so crowded that disinherited and destitute men and even their families lived miserably on rafts in the mangrove swamps. It is said that sometimes 4 hungry men had to make a meal from a single coconut. A crude maximum estimate of the population of Yap at that time can be derived from a detailed map of 3 typical villages, made in the field by one of us (Schneider). Numerous platforms of coral rock are indicated on this map, and today represent both abandoned and occupied

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dwelling sites. Taking the most sparsely populated village as representative of the entire land surface of Yap, one may estimate the total number of house sites now present in the islands. If each site was occupied by an average of 4 people, and if all sites were ever inhabited at one time, we obtain a grand total of 51,000 islanders at the peak of overpopulation.

If 51,000 people ever actually lived on Yap, the population density would have been about 1,300 per square mile. Comparable densities on the most crowded Micronesian islands today are given in the 1952 report on the administration of the Trust Territory of the Pacific Islands, by the United States to the United Nations. Among these densities are Nama (2,093), Losap (1,892), Eauripik (1,477), Pingelap (914) and Kapingamarangi (892). These values are of the same order of magnitude as the estimate for Yap, but all of them apply to low-lying islands whose comparability with Yap is limited. The inland hilltops of Yap do not permit intensive cultivation, while most low islands are more uniformly arable. Relative to its land area, too, Yap has less extensive tidal flats for fishing than do most low islands. Finally, all of the house platforms in Yap may never have been simultaneously occupied. If an entire family dies out, its ghosts are believed to haunt their former homestead, so that other Yapese are afraid to move in. For all of these reasons, 51,000 may be an excessive estimate of the former population of Yap.

We cannot follow quantitatively the earlier years of the depopulation, but table 1 shows its continuation from 1899 to 1946. Although most of the population totals in this table are the direct results of various censuses, others had to be calculated indirectly. For several census years in the Japanese period, Yap was part of a district or administrative aggregate of western Micronesian islands, of which Yap's own population comprised 61% in 1930. For 1935, the Yap total was obtained by subtracting the number of Chamorros then living in Yap from the total number of non-Japanese there. This figure was again very nearly 61% of the district population. Because of this resemblance to the percentage for 1930, the Yap totals for 1920, 1925, 1936 and 1937 are taken as 61% of the district totals for these years.

The existence of this depopulation has been recognized by all three of the nations governing Yap during this century: Germany, Japan and the United States. German authors of official reports from Yap to the Reichstag, from which the 1900-11 census totals were taken, primarily

TABLE 1

Successive Population Totals of Yap Islanders

CENSUS YEAR	GOVERNING POWER	TOTAL POPULATION	RATE OF CHANGE PER YEAR IN PERCENT	SOURCE OF DATA
1899	Spain	7,808	——	Catholic mission data after Yanaihara ('39)
1900	Germany	7,464	—4.4	German government
1903	"	7,156	—1.4	" "
1905	"	6,641	—3.7	" "
1910	"	6,328	—1.0	" "
1911	"	6,187	—3.8	" "
1915	Japan	5,790	—1.6	Matsumura ('18)
1920	"	4,988	—3.0	61% of Yap district total in Yanaihara ('39)
1925	"	4,401	—2.5	"
1930	"	3,863	—2.6	Nanyo Gunto ('32), vol. 2
1934	"	3,665	—1.3	Japanese Government Annual Report ('36) to League of Nations Mandates Commission
1935	"	3,556	—3.0	Recomputed from Yanaihara ('39)
1936	"	3,467	—2.4	61% of Yap district total in Yanaihara ('39)
1937	"	3,391	—2.3	"
1946	U. S.	2,582	—3.0	Census by the authors
1947	"	2,607	+1.0	"
1948	"	2,625	+0.6	"
1949	"	2,694(?)	+2.4(?)	Marshall ('53)
1950	"	2,720	+1.1	"
1951	"	2,774	+1.9	"

considered the medical aspects of the decline, and attributed its long duration to epidemics and a consequent high mortality among the Yapese. The chief Japanese work on the depopulation was carried out by Fujii ('34) in response to queries from the League of Nations Mandates Commission to the Japanese government. His studies dealt with the health of the Yapese, both in its effects on mortality, and on their fertility.

Since the American occupation in 1945, two studies of the demography of Yap have been carried out. One was an unpublished census of Yap by John Useem in 1946. The second was the field research on which much of the present paper is based. It was part of the Coordinated Investigation of Micronesian Anthropology (CIMA), as described by Murdock ('48A, '48B). One of the many anthropological organizations which sent investigators into Micronesia was the Peabody Museum of Harvard University. The Harvard project was financed both by the museum and by the Office of Naval Research, and was carried out by the authors, together with Dr. William D. Stevens. A joint report to the Pacific Science Board, National Research Council, was a preliminary account of the findings presented here (Hunt et al., '49).

In 1949, the Navy hospital ship U. S. S. *Whidbey* visited Yap, and its staff carried out medical examinations, by both clinical and laboratory techniques of 2,193 islanders. McNair et al. ('49) have published the findings of this survey.

Thanks to Dr. H. L. Marshall, Director of Public Health, Trust Territory of the Pacific Islands, population totals for Yap in 1949, 1950 and 1951 are appended, even though he has doubts as to their accuracy.

DEMOGRAPHIC METHODS

All of the foregoing sources are incorporated into the present paper, especially material from the census by the Harvard expedition of 1947-48. The field methods used in this census were a function of the smallness and isolation of Yap and the peculiarities of its social organization. Two of the authors (Kidder and Hunt) traveled together from village to village with parties of Yapese census interviewers. Two or more small hamlets could usually be reached in a day, or else one larger community. Since modern Yap has about 100 inhabited villages, it was impossible to define one enumeration day for the whole area. Instead, the date of the interviewing for a particular village was taken as its enumeration day.

Errors of enumeration almost inevitably bedevil census workers. Where a population is enumerated on successive days, internal migration during the census may lead both to incomplete registration and to double enumeration. Fortunately, external migration was not a source of error because of the isolation of the islanders. Errors were controlled by a series of checking devices which made use of two features of Yapese social organization. One was its grading by sex and age, and the other was its patrilocal extended family. For each sex, the age-grading system

isolates groups of approximate age-mates at formal gatherings. At each village, a Yapese census interviewer would obtain a list of all the villagers in each age grade from the local inhabitants. Secondly, and never concurrently with the first list, an interviewer would obtain a list of all the occupants of each familial residential area. Before leaving the village, both lists were cross-checked with the incoming individual census schedules. All discrepancies were corrected before leaving the village.

Each individual census schedule was then used for secondary checks on the accuracy of enumeration. Every schedule contained the names of many persons other than the enumeratee himself. These others included the name and (if living) the present village of the enumeratee's real and foster parents, all progeny of his mother besides himself, his present and divorced spouses, and real and adopted children. If any of these individuals had died since the beginning of the American occupation in 1945, his death was checked against all of the other independent sources of vital statistics. Cross checking revealed whether schedules were available on every living relative of the enumeratee, and whether common data on the two schedules were in agreement. If the villages of these relatives had not yet been visited, each relative's name was entered on a " loose ends " file to be cleared up during later enumeration days.

In each of the 10 districts into which Yap had been divided during the German regime, the authors hired a vital statistics reporter. In obtaining primary household or extended family lists, the occurrence of any pregnancy or death since the American occupation was noted. Finally, all of these events were checked against the births and deaths which had been entered in the register of vital statistics kept by the American administrators.

The interviewers attempted to account for the time and outcome of every pregnancy of every living female Yapese. Not only the occurrence, but the dates of most of the live births during the Japanese period were obtained from the remarkably complete, original registers of vital statistics kept by the Japanese policemen in Yap. The terminal dates of other pregnancies were interpolated as accurately as possible for each woman, on the basis of well-known events in recent Yap history such as typhoons and major ceremonials, and also through comparisons of these dates with the years of birth of living persons which had been entered in the Japanese records.

Before the American occupation in 1945, Yap men were much more

likely to go overseas than the women. The number, time and duration of such absences were therefore recorded for every male. Under the Americans, migration has been virtually limited to the few young adults who have gone temporarily to Guam, Truk or Fiji for training as teachers, nurses, or native medical practitioners.

The Harvard census produced a body of demographic information on a non-literate society which is relatively abundant and accurate. The year of birth of nearly all of the islanders born since 1914 is known, and even the ages of other individuals born since the beginning of the Spanish occupation in 1885 are fairly accurate because of the close correspondence of the Yapese age-grading system with chronological age. In addition to the census, the physical anthropologist (Hunt, '50) measured series of both sexes, and considerable ethnographic information was gathered by Schneider, Stevens and Hunt.

HYPOTHESES CONCERNING THE DEPOPULATION

The size of a population of organisms can be compared to the level of a lake, with births and immigration as the inflow, and emigration and deaths as the drainage. In a declining population, the losses evidently exceed the gains. The remainder of this paper deals with a series of factors which in some cases probably influence demographic changes in human societies, together with our attempts to evaluate their importance in Yap. These factors include the following:

High and disadvantageous mortality because of diseases and neglect.

Inadequate reproduction because of:

- Male absenteeism from Yap
- Malnutrition and physical deterioration
- Intestinal parasites
- Reproductive pathologies and abortions
- Patterns of copulation, contraception, fecundity and fertility.

Finally, the increase in the birth rate in recent years is related to improvements in health, morale, and the Yapese way of life.

DISEASES, NEGLECT AND MORTALITY IN YAP

The major causes of death among the Yapese are fairly typical of those found among Pacific islanders, and include both chronic and epidemic infections. Some of the peaks in the annual rates of depopu-

lation, as recorded in table 1, seem to be related to these epidemics. These rates have been calculated from the compound interest formula. Letting n equal the number of years between censuses, P_t the terminal census total, and P_i the initial one, we solve for r, which is the geometric mean rate of change per annum:

$$P_t = P_i(1 + r)^n.$$

For the entire interval from 1899 to 1946, the mean rate of decline is —2.3% per year. The rates between population totals in table 1 vary considerably from this value. Some, but not all, of this variation probably occurs because different methods of census enumeration were employed for different years. Without considerable errors, the data do not fit this or any other semilogarithmic curve. When measurements of somatic growth or numerical changes in living populations fit such curves, biologists are likely to assume that factors affecting these trends have operated uniformly through time. Such uniformity seems not to have been true of Yap, partly because of the episodic effects of epidemics on mortality.

For the German period (1900-1914), the intervals with the severest depopulation coincide with 2 known epidemics. In October, 1903, 50 Yapese died of some kind of influenza, and from 1909 to 1911, a typhoid epidemic raged. Yapese informants described 3 epidemics during the Japanese period (1914-1945), but the exact disease in each case is uncertain. The first epidemic may have been influenza in 1924, the second diphtheria in 1925, and the third amebic dysentery in 1936. The census data for Yap during these years are too incomplete and indirect to show the effects of these later epidemics.

For the period 1917-29, Fujii ('34) presents the average annual numbers of births and deaths. If we assume that the depopulation at this time represented only the excess of deaths over births, approximate average crude birth and death rates can be calculated for the year at the midpoint of this interval (1923) by the compound interest formula. The rate of decline from 1915 to 1930 by this formula is —2.66% per year. Using this rate, the 1923 population is estimated to have been 4,667. This number serves as the basis for the average birth and death rates for 1917-29. From Fujii's data alone, such rates are calculated for 1930, and for 1946 to 1951 they are computed from American sources.

Table 2 indicates that the crude death rate was about 40 per thousand in the Japanese period. The range of national crude death rates for

TABLE 2

Yap Births, Deaths and Calculated Crude Rates, 1917-1951

YEARS	POPULATION TOTAL	ANNUAL LIVE BIRTHS	CRUDE BIRTH RATE	ANNUAL DEATHS	CRUDE DEATH RATE
1917-29 (estimated, 1923)	4,667	67	14.4	181	38.8
1930	3,863	59	15.3	167	43.3
1946	2,582	70	27.1	84	32.6
1947	2,607	82	31.4	59	22.6
1948	2,625	66	25.2	53	20.2
1949	2,694(?)	71	26.4	48	17.8
1950	2,720	97	35.6	54	19.9
1951	2,774	100	36.1	48	17.3

1940, cited in Dublin et al. ('49), is from 9.2 in New Zealand to 26.5 in Egypt. It is therefore evident that the Yap islanders experienced a high mortality under the Japanese. With such a death rate, only immigration or a correspondingly extreme birth rate could have arrested the depopulation. Under the American regime, however, the death rate has fallen by about 50%.

Very little is known of age-specific death rates during the Japanese period or earlier. Price ('36) alleges that infant mortality during the Spanish regime, prior to 1900, was an improbable 800 per thousand, and that it was still at 390 per thousand in 1929. On presumably better authority, however, Fujii ('34) says that in 1417 births from 1917 to 1929, the infant mortality was 133 per thousand, mainly as a result of acute enteritis. In the United States nearly a century ago, comparable infant death rates prevailed (1 in 6, according to Dublin et al., '49). Since the American occupation of Yap, infant mortality has decreased, as shown later in abridged life tables for both sexes.

The greatest killer of the older islanders is probably pulmonary tuberculosis. It is cited by the Germans, and Fujii found it to have been active in 8 of the 9 Yapese whom he examined at necropsy. The *Whidbey* survey made mass chest roentgenograms and skin tuberculin tests in Yap, and McNair et al. ('49) state that 95% of a sample of 1,112 Yapese showed positive tests with both first and second strength purified protein derivative. The percentage increased sharply after the age of 10. Active pulmonary tuberculosis, however, occurred mainly in individuals more than 50 years of age, and was of the adult or reinfection type.

The evidence suggests that at least some of the Yapese have resistance to this disease, but without adequate histories of individual infections, this conjecture cannot be proven.

Other important chronic diseases of the Yapese are leprosy and intestinal parasites, and formerly included yaws. Over 50 Yapese have been sent to a leprosarium on Tinian where modern treatments are being given to them. The parasitic infestations and yaws of the Yapese will be considered later.

A total of 196 Yapese died during the period 1946-48, so that the transformation of their age-specific mortality into life tables is questionable because of possible sampling fluctuations of the data. The precision of the original vital statistics, however, made these computations seem worth while. For ages 0–5, the tables were calculated by a method suggested by Greville ('43) because accurate data were available on Yapese infant mortality. Later ages were computed by the procedure of Reed and Merrell ('39). These tables represent the pattern of mortality at the time of transition from a decreasing to an increasing population.

In these tables, the expectations of life at birth resemble those of Venezuela in 1941-42 (Dublin et al., '49, p. 344), but unlike nearly all civilized populations, in Yap the females have a shorter expectation of life than the males. Female infants below the age of one year are three times as likely to die as males, but at later ages, children of both sexes show similar mortality. In the earlier childbearing years (15–24), women are less viable than men. Such a reversal at these ages is not uncommon in peacetime in human groups in a poor state of health (Taeuber and Beal, '44). After 65 in Yap, the expectation of life is shorter for females than for males, perhaps because of neglect. At other ages, male mortality exceeds that of females—the usual finding in both human beings and lower animals (Hamilton, '48).

A phenomenon often seen in populations of Pacific islanders is their masculine sex ratio (Keesing, '52). This imbalance has been true of Yap at least throughout this century (Senfft, '03; Nanyo Gunto, '32), and the ratio was 114 in 1948. In the absence of appreciable migration, such a pattern must reflect a highly masculine sex ratio at birth, a high mortality of females, or both. Table 4 shows the annual sex ratios of births for 1946 through 1951. The first three years have been extensively cross-checked. The last three are from government statistics and are therefore perhaps more likely to show under-representation of females.

TABLE 3

Abridged Life Tables for Yap Males and Females, 1946-48

AGE INTERVAL	NUMBER ENTERING EACH AGE	PROBABILITY OF DYING	NUMBER DYING	NUMBER LIVING AT EACH AGE	TOTAL YEARS REMAINING TO SURVIVORS	AVERAGE YEARS OF LIFE REMAINING TO SURVIVORS
x to $x+n$	l_x	${}_nq_x$	${}_nd_x$	L_x	T_x	e_x
MALES						
0–	100,000	.0428	4,280	96,901	4,651,700	46.52
1–4	95,720	.0291	2,785	375,278	4,554,799	47.58
5–9	92,935	.0181	1,682	460,010	4,179,531	44.97
10–14	91,253	.0124	1,132	453,548	3,719,521	40.76
15–19	90,121	.0247	2,226	445,594	3,265,973	36.24
20–24	87,895	.0431	3,788	439,646	2,820,379	32.09
25–29	84,107	.0631	5,307	398,974	2,380,733	28.31
30–34	78,800	.0850	6,698	377,761	1,981,859	25.15
35–39	72,102	.1073	7,737	341,533	1,604,098	22.25
40–44	64,365	.1313	8,451	300,909	1,262,565	19.62
45–49	55,914	.1565	8,751	257,741	961,656	17.20
50–54	47,163	.1842	8,687	214,022	703,915	14.93
55–59	38,476	.2180	8,388	171,214	489,893	12.73
60–64	30,088	.2573	7,642	130,792	318,679	10.59
65–69	22,346	.3127	6,988	94,222	189,887	8.41
70–74	15,538	.4922	7,559	57,258	93,665	6.10
75–79	7,799	.5050	3,938	36,407*	36,407	4.67
80–	3,861		3,861			
FEMALES						
0–	100,000	.1413	14,130	88,870	4,460,886	44.61
1–4	85,870	.0210	1,803	338,944	4,372,016	50.91
5–9	84,067	.0183	1,538	416,041	4,033,072	47.97
10–14	82,529	.0134	1,106	410,380	3,617,031	43.83
15–19	81,423	.0484	3,941	397,975	3,206,651	39.38
20–24	77,482	.0584	4,525	376,083	2,808,676	36.25
25–29	72,957	.0532	3,881	354,934	2,432,593	33.34
30–34	69,076	.0551	3,806	335,947	2,077,659	30.08
35–39	65,270	.0654	4,269	315,881	1,741,712	26.68
40–44	61,001	.0785	4,789	293,305	1,425,831	23.37
45–49	56,212	.0992	5,576	267,411	1,132,526	20.15
50–54	50,636	.1221	6,183	237,989	865,115	17.08
55–59	44,453	.1543	6,859	205,356	627,126	14.11
60–64	37,594	.1949	7,327	169,898	421,770	11.22
65–69	30,267	.2654	8,033	131,936	251,872	8.32
70–74	22,234	.4772	10,610	84,872	119,936	5.39
75–79	11,624	.8260	9,601	34,964*	34,964	3.01
80–	2,023		2,023			

* This is ${}_\infty L_{75}$ and not ${}_5L_{75}$.

Table 4 indicates that a high sex ratio has been recorded for Yap, for unknown reasons. As shown in the life table, this initially high masculinity is increased by high female mortality in infancy, the early years of childbearing, and extreme old age, but is diminished by higher male mortality at most other ages.

TABLE 4

Total Births and Sex Ratios at Birth, Yap, 1946-51

YEAR	TOTAL BIRTHS	SEX RATIO	SOURCE
1946	70	133	Census by the authors
1947	82	160	
1948	66	89	
1949	71	109	Marshall ('53)
1950	97	131	
1951	100	127	

The combination of a highly masculine sex ratio at birth and a high female mortality in the first year of life is suggestive of female infanticide, but we found no direct ethnographic evidence of this practice and are not yet convinced that it explains these findings. Our observations of child care also revealed no relative neglect of infant girls.

The abrupt increase in the birth rate in Yap since the American occupation will be discussed later.

MALE ABSENTEEISM FROM YAP

Permanent immigration and emigration have had no appreciable effects on the depopulation. Only a handful of foreign immigrants now live among the Yapese, and some of these are undoubtedly transients. A few Yapese of both sexes have permanently emigrated to Palau, Truk, the Marianas, Ponape and even Japan. Temporary emigration of men from Yap, however, has been very prevalent in the past. Most of these men worked in the few commercially profitable German or Japanese enterprises in Micronesia, especially the phosphate mines at Angaur in the Palaus. These mines attracted laborers from many Micronesian islands. The wages and working conditions were good, and a large majority of the able-bodied Yap men gladly volunteered to work there. Some stayed abroad for many years, and repeatedly returned to their jobs after brief visits home.

Routine questions on the census schedules ascertained the number of trips abroad and the duration of each stay for every Yap male. A study was made of the men over 30 years of age by dividing them into those who had been abroad less than 5 years, and those who were away for 5 years or longer. Determinations of the average number of recognized progeny were then made, and a critical ratio calculated to test the significance of the difference observed. These findings are presented in table 5.

TABLE 5

Duration of Male Absenteeism from Yap and Number of Recognized Progeny

DURATION OF ABSENCE	*N*	NUMBER OF RECOGNIZED PROGENY Mean S. E.	*C. R.*	*p*
0–4.9 years	332	1.9 ± 0.2		
5.0 or more years	237	2.2 ± 0.2	1.1	0.27

Contrary to expectation, the men with the longer absences had a slightly larger number of recognized offspring, but this difference is not statistically significant. This test indicates that long absenteeism *per se* did not decrease the prolificacy of Yap men, probably because their employment abroad was typically discontinuous, with trips home often enough to sire some, at least, of the children considered by the community as being their own.

MALNUTRITION, PHYSICAL DETERIORATION, AND REPRODUCTION

An indirect but illuminating study of the reproductive potentials of the Yap islanders lies in their growth, diet, and body structure. In the past, a few physical anthropologists have dealt with these factors in evaluating the stability, florescence and deterioration of human societies and cultures. Hooton ('30), for example, found that the Indians of Pecos Pueblo, New Mexico, in successive generations showed facial shortening and enlarged occipital tori during their depopulation after the Spanish conquest. Angel ('44, '47) found that a better diet, relatively long life span, freedom from dental caries, and population increases accompanied the high points of cultural creativeness in the history of Greece. Correspondingly, the life span and population total decreased, and physical and dental deterioration set in, before the collapse of the Byzantine Empire.

Price ('39) investigated the malnutrition and physical deterioration of many formerly isolated human groups during their assimilation into the modern world economy. He found that this assimilation often involved an abandonment of the traditional local foods and the substitution of refined foreign products such as biscuits and sugar. The effects of such dietary innovations have been monotonously similar on human beings in much of the world, regardless of race, and include rampant dental caries, skeletal and facial malformations, difficult childbearing, and perhaps even reduced fertility.

The evidence for physical deterioration as a part of the recent history of Yap might ideally have been studied by comparing early Yapese skeletal remains with the findings on the living population. Since it was impracticable to collect such remains from the village cemeteries, other sources of data were used instead. These sources included a series of aboriginal skulls from Guam, dating from just before or during the Spanish conquest in the 17th century, successive anthropometric samples of living Yapese adults dating from 1876 to 1948, and dental comparisons of the Yapese with other Pacific islanders.

If physical deterioration is related to a poor diet, the foods of Yap deserve consideration. Actually, the Yapese have been slow to adopt foreign foods. The islands support an abundance of edible plants which are seldom threatened except by occasional typhoons. These storms usually damage the plants, but seldom kill them. In recent generations, at least, no serious famines have contributed to the depopulation.

Like most other Pacific islanders, the Yapese chiefly live on root crops, fruits, fish and shellfish. The nutritional adequacy of such dietaries is uncertain, and may be highly variable from place to place. Alpert ('46) regards such diets in Micronesia as seriously deficient in proteins, calcium, iron, ascorbic acid, the B-complex vitamins, and calories. On the other hand, Price ('39) praises highly the quite similar aboriginal diets of Melanesia and Polynesia.

The most illuminating study of such diets is that of Hipsley and Langley ('53) in 4 New Guinea villages. The inhabitants of these villages probably have lower nutritive requirements than do Americans, because of their smaller bodies, tropical environment, less active mode of life, and the reduced specific dynamic action of their strongly vegetable diet. Hipsley and Langley believe that these people ingest enough calories, even though they generally do not become obese in middle age. They consume enough thiamin and ascorbic acid, but their protein and

calcium intakes are not so easy to evaluate. The nutritive value of vegetable protein is uncertain, but a genuine deficiency seems to occur in these dietaries. Calcium intake averages less than half of that specified in the standards for the United States calculated by the National Research Council, but in three villages with plentiful sunlight, very little rickets could be found in wrist roentgenograms of infants less than two years old.

In the absence of such data on the diet of the Yapese, we shall consider their gross physical state in its comparative, historical and developmental aspects, especially as related to their nutriture.

Our best evidence on the gross physical state of Micronesians in past centuries comes from old skeletal remains from Guam. Prior to the Spanish conquest, the Guamanians lived much as the Yapese do today, except that the Guamanian diet included somewhat more rice and seaweed. Since the dentition is an important indicator of nutritional status, a study by Leigh ('29) on the teeth of 106 old skulls from Guam gives us a valuable standard for evaluating modern Yap teeth.

Most of these skulls had an edge-to-edge occlusion of the incisors, although Leigh does not cite statistics, and only 15% showed any teeth out of line in the dental arches. The teeth were often discolored from betel chewing, but caries occurred in only 19 skulls, of which 11 showed senile lesions of the cementum. Many molars had faults and fissures where the cusps coalesced. In Guamanians who had died past the age of 30, teeth were often lost, especially in females, and the apparent reason for these losses was periodontoclasia.

TABLE 6

Incisor Occlusions and Crowding in Yap Adults

SEX	AGES	*N*	UNDER-BITE	EDGE TO EDGE	SLIGHT OVER-BITE	PRO-NOUNCED OVERBITE	CROWDING OF TEETH		
							ABSENT	SLIGHT	PRO-NOUNCED
Male	20–49	343	2.0	45.2	43.2	9.6	42.7	46.0	11.3
Female	18–49	129	3.1	43.4	40.3	13.2	61.5	28.5	10.0

In most respects, the dentitions of the living Yapese are fairly similar. Table 6 illustrates the incisor occlusions in a series of adults. No significant sex difference was found, and although the edge-to-edge bite is the commonest condition, it seems to be somewhat less prevalent

than among the aboriginal Guamanians. Crowding is also somewhat more evident in Yap than in Guam. In Yap, it occurred mainly in the lower incisors and canines, such that a few teeth were slightly rotated or displaced. This condition was recorded as "slight" crowding. In "pronounced" crowding, all of the lower front teeth and premolars were considerably displaced or rotated, and in many cases, the upper front teeth were likewise out of alignment. These cases, however, were almost never as serious as one routinely sees in an orthodontic clinic, and were not accompanied by gross asymmetries of the nasal septum nor mouth breathing. The women showed significantly less crowding than the men except in the "pronounced" category.

As a result of their similar habit of betel chewing, the Guamanians and Yapese usually exhibited brownish, discolored teeth. There is no evidence, however, that this habit causes dental caries. Table 7 indicates that the younger Yap men have slightly more decayed teeth than the women. This difference may stem from the consumption of foreign foods by some of these men during their periods of work in foreign settlements—whether abroad or in Yap itself. In the older Yapese, the women have more caries. In general, the teeth of these people are fairly resistant to decay, but may be more carious than those of the ancient Guamanians.

TABLE 7

Percentages of Carious Teeth in Yap Adults

AGES	*N* Males	% CARIOUS Teeth	*N* Females	% CARIOUS Teeth
15–19	38	2.48	25	2.09
20–24	74	1.71	23	0.73
25–29	82	1.88	33	2.05
30–34	83	2.00	19	2.74
35–39	67	1.33	21	1.59
40–44	25	2.08	12	2.92
45–49	14	1.58	9	2.34

Other evidence on the low incidence of caries in Yap can be seen in table 8, in which data are combined from two investigators who studied this disease in Micronesian school children. Kuwahara ('41) worked out the incidence of caries in Palau, Truk, Ponape and Jaluit, and Hartmann ('47) studied two groups on Yap. Hartmann's two series

included a group of Yap native children, and also a sample of highly acculturated Chamorro children who lived at that time in Colonia, Yap. The diets of these two groups differed mainly in that the Chamorros ate more bread and rice. The statistics from all these groups show that the Yapese native children were the most caries-resistant of any. The lack of relationship between betel chewing and caries in these children can be seen in the fact that outside of the Chamorros and Yapese, only the Palauans chew betel.

TABLE 8

Percentages of Carious Teeth in Micronesian School Children

Kuwahara ('41)		Hartmann ('47)	
Ponape	57.67	Chamorros (Colonia, Yap)	10.28
Jaluit	42.83	Yapese	5.84
Palau	38.57		
Truk	13.16		

Table 9 shows that the loss of teeth in Yap is not unlike that of the prehistoric Guamanians, and sets in during the middle thirties. A similar rate of loss has also been found in three New Guinea villages on substantially aboriginal diets (Sinclair et al., '53). In the Yapese, the standard deviations of the numbers of remaining teeth increase after the thirties, since some individuals lose teeth faster than others in middle age. During this period of loss, the teeth become non-vital,

TABLE 9

Mean Number of Teeth Present in Yap Adults

AGES	*N* Males	NUMBER OF TEETH Mean	σ	*N* Females	NUMBER OF TEETH Mean	σ
15–19	38	28.6	1.3	25	28.7	1.1
20–24	74	30.1	1.7	23	29.9	1.7
25–29	82	31.2	1.4	33	31.1	1.5
30–34	83	31.3	1.5	19	30.8	1.5
35–39	67	30.4	4.3	21	30.0	2.7
40–44	25	26.9	8.2	12	28.6	6.0
45–49	14	26.1	8.2	9	28.4	4.7
50–54	8	22.3	11.6	9	26.4	10.1

more and more loose, and finally drop out. Elderly Yap informants said that the actual loss of a tooth was seldom painful. These symptoms are probably indicative of periodontoclasia. The possible relationship of betel chewing to this loss of teeth is unknown.

The emergence of the third molar teeth in Yap males, as shown in table 9 and in other data as well, tends to be late. In a series of Harvard undergraduates whose ages at third molar emergence have kindly been supplied by Dr. Clark W. Heath, of the Harvard Study of Adult Development, the median age of emergence was about 20 years. In Yap males it was 22. These teeth are slightly less apt to emerge in Yap females than in males and, as a result, up to the age of 39, the women have fewer visible teeth than the men. After this age, the males lose teeth faster than the females, unlike these rates in the Guamanian crania cited previously. In Yap, the years of lactation and pregnancy are not a time when women lose teeth faster than men. In the much more carious teeth of the people of Puerto Rico, however, Thieme ('53) found that between the ages of 20 and 45 years, the women lost an average of 0.58 teeth per year, while the men lost only 0.29.

TABLE 10

Successive Anthropometric Series of Yap Adults

AUTHOR	DATE OF MEASUREMENTS	*N*	STATURE RANGE	STATURE MEAN	NOSE BREADTH	HEAD LENGTH	HEAD BREADTH
Males							
Miklucho-Maclay	1876	30	150–169	—	—	—	—
Hambruch	1906	7	———	164	41	188	146
Hirako	1915	8	159–171	164	—	191	150
Hasebe	1927	46	———	160	42	189	146
Arai	1939	189	———	162	44	189	148
Hunt	1948	347	146–178	161	42	189	150
Females							
Miklucho-Maclay	1876	11	136–158	—	—	—	—
Arai	1939	75	———	149	39	179	141
Hunt	1948	143	135–164	150	37	179	143

From 1876 to 1948, 6 investigators have measured series of living Yap adults, and their findings are presented in table 10. If these data suggested any recent systematic shrinkage in Yapese bodily dimensions, one might argue that this trend was indicative of deteriorating nutriture.

No such decrease was found. In spite of the smallness of some of these samples, table 10 indicates that the Yapese today are much the same size as their ancestors were more than 70 years ago. This metrical stability is quite unlike the increase in stature during recent generations in many civilized populations (Bowles, '32), and seems to be only one of a great many manifestations of dietary and cultural conservatism still prevalent in Yap.

Alpert ('46) found a number of characteristics in many Micronesians which he attributed to dietary deficiencies. He did not examine any Yapese for these signs, however. Included in his list were vascularity and thickness of the conjunctiva, redness of the tongue with a fissuring of the surface, atrophy and fusion of the filiform papillae, and hypertrophy of the fungiform papillae. A few Micronesians showed an actual edema of the tongue. Alpert believed that these symptoms resulted from deficiencies of the B vitamins, especially niacin. A prevalent recession and hypertrophy of the gums he attributed to a deficiency of ascorbic acid.

In the medical survey conducted by the *Whidbey*, McNair et al. ('49) observed conjunctivitis in about 10% of the Yapese. Other gross nutritional deficiencies were not apparent, and these authors think that only subclinical cases exist in Yap.

Examinations by Hunt during the Harvard anthropometric survey revealed many cases of fissuring of the tongue. Sloughing and bleeding of the gingival and oral mucosa also appeared, but in each case the islander said that he had accidentally burned his mouth from putting too much lime in his betel quid. This betel irritation makes the identification of avitaminoses uncertain. Since the Yapese eat numerous oranges and pineapples from their own islands, it is not too likely that they are deficient in ascorbic acid.

Alpert also mentions the slow maturation of the Micronesians as evidence of their inadequate diet. Children in Yap certainly mature less rapidly than recent series of American children. For 1948, the median age of menarche in Yap girls was determined from the number of individuals at each age from 10 to 17 years who had or had not entered the postmenarcheal age grade, as noted in the census. This median age was 14.3 years, which is a year or more older than mean menarcheal ages found in most recent American growth studies (Stuart, '46). Smoothed mean statures for adults at different ages indicate that full adult stature is reached at about 26–27 years in Yap men, and 20–24

years in women. For males, full stature is reached some 2 years later than in American Whites (Randall, '49), as is the emergence of their third molar teeth.

The interpretation of this slow maturation is difficult. Hipsley and Langley ('53) think that diets deficient in protein in New Guinea slow down the growth of the people there. Mills ('42) believes that hot and humid tropical climates retard human growth. Craig and Faust ('45) observe that children with severe infestations of intestinal parasites mature slowly. Some or all of these explanations may apply to Yap.

Childbearing in Yap is usually easy, and puerperal sepsis is rare, even after deliveries by island midwives (McNair et al., '49). After being delivered in the hospital, a Yap woman may walk off, carrying her newborn child.

In general, the caloric nutriture of Yapese adults seems adequate, but they are among the growing list of Pacific island peoples in whom obesity in middle age has been observed to be rare (Keesing, '52; Keys and Brožek, '53; Hipsley and Langley, '53).

In general, the preceding data do not indicate any obvious or severe malnutrition in Yap. Depopulation can evidently occur in a human group with little or no concomitant physical deterioration.

INTESTINAL PARASITES

Another phenomenon of possible relevance to the depopulation is the great prevalence of intestinal parasites in the Yapese. Fujii ('34) found that 98.9% of a large Yap series harbored the nematode *Trichostrongylus*, 50.3% had hookworm (ancylostomiasis), 33.2% *Ascaris* (roundworms), and 3.2% the pinworm *Enterobius* (*Oxyuris*). An unpublished study by a medical officer on Yap, Dr. E. C. Cowart, showed that 97% of a sizeable sample of Yapese harbored at least two of these species of parasites in 1948. When the American medical officers tried to eradicate these infestations by treatments with hexylresorcinol crystoids, practically all of a group of Yapese became reinfected in a few weeks. These infestations probably result from Yapese habits of defecating in the bush, walking barefoot and sitting on polluted ground, eating raw food and drinking unboiled water.

The *Whidbey* survey of stool specimens from 1,294 Yapese revealed that 83% showed parasitic infestations. *Trichostrongylus* and *Ancylostoma* were the commonest species found, as in the Japanese studies, and other types were only sporadically present.

The possible relevance of these infestations to the depopulation may be inferred from data in textbooks of parasitology such as Craig and Faust ('45). Evidently *Ancylostoma* and *Enterobius* are both known to impair human reproduction. In some cases, *Ancylostoma* may cause impotence in men and stillbirths in women. *Enterobius* may even infest the female genital tract and enter the abdominal cavity by way of the uterine tubes.

Although intestinal parasites may have slightly depressed the birth rate in Yap, it is also true that seriously infested peoples such as the Javanese and Egyptians are among the most rapidly increasing populations in the world.

REPRODUCTIVE PATHOLOGIES AND ABORTIONS

The most intensive survey of the diseases of the genitals in Yapese of both sexes was carried out by Fujii ('34). American physicians so far have had more limited experience with this problem. For example, members of the *Whidbey* survey made urogenital examinations of the men only (McNair et al., '49).

Both surveys found practically no syphilis in Yap. Fujii seldom saw indurated chancres, and McNair et al. ('49) report that "no case of primary chancre was found, nor were secondary skin manifestations found among the men or women." Fujii states that chancroids are also rare.

In spite of the considerable experience of many physicians in Yap, the incidence of gonorrhea is still in doubt, and we do not know whether it has changed during the American occupation. Fujii ('34) thought that this disease was the chief cause of the former low birth rate, and attempted to discover its incidence by both clinical and microscopic examinations of thousands of Yapese of both sexes. In 1,102 women, 42.8% had gonorrheal vaginitis and endometritis, and Fujii suspected that inflammations of the tubes and ovaries were also prevalent. American physicians have often seen mucus blocks, cervicitis, and yellow exudate from the vagina in Yap women. Fujii also states that in 1,252 Yap males aged 8 to 60, 46.8% showed epididymitis, prostatitis or urethritis, but gonorrhea was positively diagnosed in only 24.8% of this entire male group. In all, Fujii believed that 784 Yapese of both sexes whom he examined were infected with gonorrhea. He treated 88 of these cases, 72 of whom were women. Subsequent to therapy, 15 of these women became pregnant for the first time.

In September, 1945, the United States Navy occupied Yap. Monthly reports sent from Yap to the Department of the Navy indicate that a dispensary was set up, and in January, 1946, 754 adult islanders were treated with arsenicals for yaws. An unspecified number of children were given 400,000 units of penicillin apiece for this disease. In February, 1946, 629 cases of yaws were treated. This program of mass therapy was so successful that only a few individuals needed further treatment. At the time of the *Whidbey* survey in 1948, no active "raspberry-like" lesions of yaws were seen, although both "tissue-paper-like" and keloid scars of former yaws were quite prevalent.

In startling contrast to the evidence of Fujii, the *Whidbey* survey of diseases of the male genitalia disclosed only 4 men with gonococcic urethritis, and one with nonspecific urethritis. We are still ignorant of whether old chronic gonorrhea in a form unrecognized by the American physicians is actually still widespread in Yap, or whether the mass treatment of yaws has somehow reduced the incidence of genital pathologies in the Yapese.

Before the American regime, Yap women used spongy wads of plant fibers to absorb the menses. These wads were sometimes kept in the vaginal canal. More recently, the women have begun to buy American sanitary napkins, and this practice may have alleviated some of their vaginitis.

According to Schwidetzky ('50), the percentages of married women in various human groups who have ever borne children range from about 75 to 95%. The converse percentages of infertile married women would be 5 to 25%. Since nearly all mature Yap women have had some marital experience, data on their infertility are worth comparing with these percentages. Within the age range of 26 to 50 years, Fujii ('34) found that 30.8% of 622 women claimed never to have been pregnant, and this incidence from 424 such women in our census was 34.4%.

In the 1,417 Yap births recorded from 1917 to 1929 by Fujii ('34), 5.9% ended in miscarriage or stillbirth. For 1,622 progeny reported by the fertile women in our census, this incidence was 5.2%. Comparable rates for Fiji in 1890 and 1891 were 5.22% and 6.13% (Krzywicki, '34), and for rural "colored" people in the U. S. Birth Registration area from 1922 to 1936, this rate was 6.37% (Strandskov and Roth, '49). Yap therefore resembles these other unhealthy groups in reproductive wastage, but since stillbirth rates are notoriously inaccurate, comparisons are risky.

If a Yap woman does become pregnant, she will not always carry her child voluntarily until term. She may deliberately induce an abortion by expedients such as drinking concentrated salt water and lacerating the cervix with a wad of leaves. Although an effort was made in our census to account for every pregnancy of every living Yap female, these women knew that both foreigners and Yap men disapprove of deliberate abortions. Some of the women who falsely reported no pregnancies to both Fujii and ourselves may actually have become sterile because of this practice, or at least afflicted with cervicitis. As in most other statistics on stillbirths, concealment of deliberate abortions probably introduces an unknown amount of error into the stillbirth rates for Yap of both Fujii and ourselves.

We believe that pathologies of the genitalia in Yap—whether venereal disease or not—considerably depressed the crude birth rate before 1946. Improvements in these conditions may have occurred since then, but are probably not the only reasons why the crude birth rate has recently doubled.

COPULATION, CONTRACEPTION AND FERTILITY

Several additional factors seem to have limited the numbers and survival of the progeny produced by Yap parents. A brief account of the individual life cycle and sexual activities of the Yap people will highlight some of these reproductive limitations.

The Yap child typically passes from a secure and well-fed infancy into a long period when he is virtually free from responsibility. Adolescents of both sexes are not encouraged to do serious work, and soon embark on premarital, somewhat secret, love affairs. Love trysting in Yap includes witty conversation, romantic songs, betel sharing, gift exchanges, and the drinking of fermented coconut sap (toddy). These encounters usually take place out of doors, in secluded parts of the village. The partners often engage in prolonged embraces and slow friction of the penis and clitoris, during which the male ejaculation occurs within or outside of the vagina. A married man is unwilling to perform this act with his wife for fear of causing her to insist on it too often, thereby making him too debilitated to work. Ordinary sexual intercourse, however, is indulged in by both unwed and married couples.

In late adolescence and younger adult years, couples will usually live together openly in marriage, generally in patrilocal residence but in a separate dwelling. These unions are not necessarily permanent, espe-

cially if the wife produces no children. The married partners typically show little overt affection for each other. Instead, both may engage in surreptitious extramarital sexual affairs. Yap adults usually go through more than one such temporary marriage, and little or no social pressure is customarily exerted on couples to stay married unless children are born. Such tentative matings usually take place before the age of 30 years, when the partners are not yet expected to have acquired the responsible habits of maturity.

Until recently, extramarital copulation for the young men also took place in their club houses. Young female entertainers were kept there as honored and respected sexual partners of the club members, and played a role comparable to that of Japanese *geisha*.

The aboriginal Yap islanders were among the many Oceanic peoples who apparently believed that sexual intercourse does not cause pregnancy, and that children result only from the intervention of supernatural beings. This opinion is still expressed by some Yapese, but does not lead to unrestrained copulation at any time or place. Coitus is theoretically forbidden when a man is fishing or constructing a canoe, a house or a road. If he becomes an important religious specialist, he is expected to remain continent for life. Continence is also enjoined on participants in sea voyages, ceremonials, and mourning for the dead. A woman should not copulate during menstruation, pregnancy, nor from her confinement until her offspring can walk and speak.

A small survey of the recall of recent sexual intercourse was carried out, using 16 adult informants from Rumung, an isolated island at the northern tip of Yap. This survey showed considerable awareness of many of these coital restrictions. It was made at a time when most of the men were harvesting trochus shells from the sea, and were therefore under the temporary ban on coitus which is connected with fishing. Although the coital frequencies revealed in this survey may be lower than usual, only 4 of the 16 informants admitted to copulation within the previous 10–15 days.

In considering this evidence, it is noteworthy that most samples of males in the U. S. aged 16–40 years admit to an average coital frequency of at least once a week (Kinsey et al., '48). The frequency reported by the Yapese is evidently much lower, but may be unrepresentatively so because of the trochus season, the small sample, or the islanders' own attitudes toward sexual intercourse. The usual jibe at a man who is weak or unwilling to work is that he has been copulating "too much."

Many Yap men said that "too much" copulation made them incapacitated or ill. Coital excesses and violations of other prohibitions against sexual indulgences lead to the death of the transgressor in several Yap folk tales, generally from fish bites or supernatural vengeance. "Too much" intercourse is defined as something over two or three copulations per month. This sentiment against "frequent" coitus makes it quite possible that the informants in our survey minimized their erotic revelations out of a reluctance to admit that they had copulated "too much."

When unmarried couples produce orgasms by friction of the penis and clitoris, this activity may reduce the likelihood of conception. Other, more deliberate, contraceptive techniques are known but seldom used, whether *coitus interruptus*, condoms, mechanical obstruction of the cervix, or douches of concentrated salt water after copulation. These measures seem to have been unimportant factors in the depopulation.

Recent evidence (Farris, '50) indicates that a woman usually tends to ovulate at about the middle of her monthly cycle, and is probably capable of conception for several hours afterwards. The timing of coitus within this cycle is therefore a significant aspect of human reproduction. In Yap, a woman is expected to remain continent during menstruation, when she is secluded in a menstrual area. During the rest of her cycle, however, the Yap people express no particular preference for the time of copulation.

During the Japanese regime, several Yap informants stated that Japanese physicians gave them lectures on how to have more children. These instructions were that couples should have intercourse during the week just before or just after menstruation. This plan was probably based on the obsolete and erroneous premise that ovulation and conception are most likely to occur at this time. If any of the Yapese followed this advice, they may have been reproductively frustrated. The degree of conformity to this plan in Yap, however, seems not to have been strict. In our opinion, it was not a major depressant of the birth rate during the Japanese period.

Recent studies of the fertility of American Whites (Farris, '50) do not suggest any simple relationship between coital frequencies and conception rates in human populations. Farris found that the number of spermatozoa in an average ejaculation of semen is maximal if the donor has not ejaculated during the previous 5 days. As the preceding interval of continence decreases below 5 days, the sperm count decreases, until at three days or less, a man with an average output of spermatozoa

generally produces too few of them at a coital orgasm to be likely to impregnate his partner. On the average, a woman should therefore be most likely to conceive at a given copulation if her partner has not ejaculated during the preceding 4 days or more.

Extrapolating these findings to the fertility of human populations, it is likely that with intervals between copulations conforming to a normal curve, two societies might have identical conception rates where one group copulated at a mean interval of much less than 5 days, while the other's interval was considerably longer.

In Yap, if the low coital rate also reflects a low total frequency of male ejaculations, most men at coitus would produce a maximum number of spermatozoa. The sexual license of the younger Yapese might also allow an unusually fecund man to impregnate more than one woman. Other features of these same coital patterns, however, may depress fertility in Yap. The spread of venereal diseases through Yapese promiscuity is an unproved but possible depressant. The instability of marriages of childless women is another. According to Pearl ('40), a woman is apt to be most fertile late in her teens or soon afterward. At these ages, many Yap women circulate from one husband to the next, and their coital experiences may therefore be episodic and irregular.

Still another limitation on the number of children in Yap stems from the reluctance of many women to have large families. A mother's burdens of gardening and cooking are considerably increased when her older children come to belong to more than one age grade. These burdens arise because each grade must be fed with rations from its own separate garden, as a part of the emphasis on rank, social distance, and separation of the sexes in Yap. Many woman therefore openly state that they hope to have only a few children in order to save themselves from too much work.

THE RECENT INCREASE IN THE YAP POPULATION

In retrospect, we shall probably never know whether the Yapese were potentially capable of a high birth rate during the depopulation. Judging from their diseases and high mortality, their burden of ill-health must have been heavy. Since the American occupation, yaws have largely disappeared, and mortality has greatly decreased. When such improvements occur very rapidly in a human group, increased fertility might reasonably be expected, even though its causes are not well understood.

Although space does not permit a full treatment of recent demographic statistics or forecasts for Yap, the gross reproduction rate for 1946-48 was 1.593, and the net reproduction rate was 1.135. The net rate falls below the gross rate by 28.8%, and this deficit indicates the persistence of a high mortality among young females, as previously shown in the life tables. The true rate of natural increase (r) per year is 4.79 per thousand. In an approximate generation (26.69 years), if age-specific fertility and mortality remained at the levels of 1946-48, the breeding population of females would increase by 13.5%. Since 1948, however, the crude birth rate has continued to rise, and mortality has still further diminished. In 1946-48, an average of 32 females were born per year. In 1949-51, however, the average was 41 girls born per year, so that by now the female Yapese are increasing still more rapidly than before. The highly masculine sex ratio at birth, and relatively low male mortality, make the increase of males still more probable and rapid in the next generation.

From the Spanish period until 1948, a small community of Chamorros from the Marianas lived on Yap near Colonia. This group has since been resettled on Tinian. In 1946, they had a crude birth rate of about 30 per thousand, and were probably quite prolific during the Japanese period as well. The Yapese living near them have slightly straighter hair than the inhabitants of more remote parts of the islands, which suggests some Chamorro admixture, but practically no Yap children in 1948 showed evidence of mixture with Japanese or Whites. Furthermore, the Yap birth rate in 1951 was still high, long after the Chamorros had left. We therefore attribute substantially all of the recent increase in the Yapese birth rate to their own sexual activities.

As the control of disease in Yap has improved, several social and cultural changes have also helped to enhance the fertility of the islanders. One such change is that few young men are now working outside of their home villages, either in Colonia or abroad. Instead, they are at home enough so that they probably have more uninterrupted sexual access to young Yap women than in the past.

A rumor was current among the Yapese in 1948 that a secret meeting on the depopulation was held by the chiefs and religious leaders in 1946. These men supposedly decided that most of the former taboos on coitus should be discontinued. Even at the time of our coital survey in 1948, however, these regulations were still invoked as explanations for alleged sexual abstinence.

The Yapese are now unquestionably undergoing considerable acculturation toward the American way of life, of which this rumor is symptomatic. Although material objects of Japanese or American origin are more numerous near Colonia, the extent of acculturation in values and behavior is not very different in the various parts of Yap.

Two other demographically important aspects of acculturation have been a relaxation of the interdining restrictions among the various age grades and between the sexes, and improvement in feminine hygiene. As more family members feel free to eat together, the domestic chores of a mother become easier, and her desire for children may increase. When a woman wants children, she may be less inclined to end her pregnancies by deliberate abortions. At menstruation, she is beginning to use sanitary napkins rather than local plants. These improvements probably have helped to alleviate female infertility and increase the birth rate.

With a higher birth rate, an increase in marital stability can also be expected, since fertile couples usually stay married for life. Stable marriages, furthermore, should increase the likelihood of additional children to be born, so that the present fairly high birth rate is maintained.

The future survival of the Yap people apparently depends on improvements in health, sanitation and marital stability, and on maintaining a high morale. If these conditions deteriorate, the population may well resume its interrupted decline. Otherwise it may continue its present moderate increase.

SUMMARY

Over a century ago, the Micronesians of Yap began to decrease in numbers. The first census of this group, in 1899, showed a total of 7,808 Yapese. In 1946, there were only 2,582. Subsequently their numbers have slightly increased.

An increase in mortality, chiefly as a result of severe infectious diseases, probably started the decline, and even after several decades of foreign rule, the crude death rate was still high. From 1917 to 1930, the crude death rate was about 40 per thousand. Poor health conditions prevailed in Yap, including 5 known epidemics and widespread yaws and pulmonary tuberculosis. The crude birth rate for 1917-30 was only about 15 per thousand, so that the depopulation continued unabated.

This low birth rate seems not to be explained by the absence of men

from Yap. Although most Yap men spent years as laborers in other parts of Micronesia, the men absent for more than 5 years had as many recognized progeny as those away for a shorter period. The absentees were seldom continuously abroad, and usually visited Yap often enough to sire some, at least, of the children attributed to them.

The low birth rate of the Yapese in the past may partially be explained by some of the pathologies of their genitalia. In the early 1930's, Fujii conducted medical examinations of thousands of Yapese, and found widespread genital infections which he regarded as gonorrhea. Under the American administration, mass treatments with arsenicals and penicillin have virtually eliminated yaws, but whether the genital diseases of the Yapese are less severe now than previously is unknown. A recent American medical inspection of the genitalia of most of the men revealed practically no gonorrhea, but whether old chronic infections were overlooked during this survey is uncertain. Another minor depressant of fertility may be the presence of intestinal parasites in nearly all Yapese.

Despite the infectious diseases of these islanders, they were and are otherwise well off physically. They eat few foreign foods. Caries and malocclusions of the teeth are rare. The children mature slowly, perhaps because of the tropical climate, intestinal parasites, or even perhaps a subclinical protein deficiency. Puerperal sepsis and other obstetrical difficulties are uncommon.

The much reduced birth rate during the Japanese period may in part have resulted from the poor health and debility of the islanders, but numerous cultural patterns in Yap seem to have limited fertility. In the culture of Yap, rank and prestige are greatly emphasized, so that men and women eat apart, and even individuals of different age grades also eat separate food. The inconvenience of this kind of housekeeping within the family leads many women to hope for only a few children. During the Japanese regime, the difficulty of raising a family when the husband was often abroad may also have minimized the desire for children. At that time, pregnancies may often have been terminated by deliberate abortions. Menstrual hygiene was also unsanitary. Along with infectious diseases in both sexes, these conditions seem to have contributed to the claim of about one third of the women aged 26–50 that they had never been pregnant.

Since the arrival of the Americans, the crude birth rate has doubled and the crude death rate halved. Health has improved, and several

social and cultural changes seem to have helped to raise fertility. Few young men are now outside of their home villages. Coital taboos are probably relaxing. More family members are eating together than previously, so that housekeeping is easier, and the mother's desire for children is probably increasing. Fewer abortions and better menstrual hygiene may be enhancing female fertility. As more children are born, marriages are becoming more stable, so that the likelihood of additional childbearing increases. With improved health and sanitation and a high morale, the population will probably continue to show a moderate increase.

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THE QUESTION OF PHYSICAL SELECTION OF MEXICAN MIGRANTS TO THE U. S. A.

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IN a recent comparison of the physique of Mexican migrants and sedentes, I presented data bearing on the question of selective migration (Lasker, '52). After their return to their home town in Mexico, those male emigrants who had first left when already mature did not differ significantly from sendentes. Under the assumptions made in that study, it appears that environmental growth factors rather than selective emigration are responsible for differences between sedentes and emigrants who had left when still immature. At least, insofar as the physical characteristics under study are concerned, there was no sign of physical correlates of self-selection or selection by others among emigrants who had returned to Paracho, Michoacán, prior to 1948. As a matter of fact, in the generation reaching adulthood during the period between the Madero revolution (1910) and the end of World War II (1945), the young men of Paracho normally looked forward to periods of temporary labor in the United States.

Such semi-permanent migration used to be typical. Over the years, however, the opportunities for such migration have been decreasing. During World War II the governments of the United States and Mexico agreed to a system of labor contracting and the prohibition of the admission of individual job-seekers. As long as the war continued, however, there was an acute labor shortage in the United States, and contract laborers, hired in Mexico, were insufficient in number to meet the demand north of the border. There was, therefore, little selection and most Mexican men who wished to go to the United States to work were able to get a contract to do so.

After the war (and until January, 1954), on the other hand, the

United States tried to enforce the policy of limiting the number of *braceros*, laborers admitted for temporary residence, and of excluding non-contractual migrants. Agents of the United States Department of Agriculture, acting for American employers, have not only recruited but actively selected the contract laborers in Mexico. Numerous men in Paracho who wished to go to the United States have travelled to San Pedro Tlaquepaque, Jalisco, to be interviewed. Some received contracts and went to the United States but many others were rejected and returned home. It seemed worth while to investigate whether, in this changed situation, selection of migrants involves a difference in physique between those who migrate and those who do not. As these later migrants come from a population a sample of which had already been measured in Paracho in 1948, this question could be answered simply by finding out which of the individuals in the sample had been hired under the new regime for work in the United States. By means of a census of Paracho taken in September 1952 we determined that of the 297 adult males measured 4 years earlier, 61 had been to the United States subsequent to 1948.

A comparison of their measurements with those who had not gone again since that year shows no important differences (see table 1). Those who went to the United States during the years 1948-1952 had, on the average, significantly broader hands, shallower chests, shorter chins, and shorter ears. The occurrence of only 4 differences as great as twice the standard error is hardly meaningful in an array of 26 measurements. Nevertheless, three of the 4 significant differences correspond to general tendencies which are suggested by the direction of the mean differences in related measurements: 1. The greater hand breadth in migrants is associated with some tendency to greater general size in stature, sitting height, biacromial diameter and all measurements on either extremity. 2. The smaller chest depth in migrants is accompanied by a possible tendency toward narrower chests and toward some smaller breadth and depth dimensions of the face and head and of head height. 3. The smaller ear height is accompanied by a tendency toward smaller ear breadth and narrower nose breadth. The shorter lower face, however, is accompanied by a tendency toward longer face in general.

It was already clear from our previous studies that migrants who, before 1948, had been in the United States during their growing years differ significantly and in characteristic ways from those who had never been or who had first gone when older (Lasker '52). It therefore

TABLE 1

Differences in Dimensions between 1948-1952 Migrants and Non-migrants

	MIGRATED 1948-1952			NOT MIGRATED 1948-1952			UNWEIGHTED DIFFERENCE	DIFFERENCE WEIGHTED FOR PAST MIGRATION	DIFFERENCE WEIGHTED FOR AGE
	No.	Mean	± s.e.	No.	Mean	± s.e.	Mean	Mean	Mean
Stature	61	1638.39	7.69	229	1622.41	3.71	+15.98	+5.19	+10.24
Sitting height	59	861.34	4.00	228	854.61	2.02	+6.73	+3.17	+2.96
Arm length	60	742.05	4.15	233	736.77	2.02	+5.28	+2.22	+3.38
Radius length	60	249.80	1.68	235	248.72	0.80	+1.08	+0.18	+0.54
Hand length	61	181.02	1.13	233	180.86	0.53	+0.16	−0.51	−0.03
Hand breadth	61	81.97	0.54	236	80.55	0.23	+1.42*	+0.97	+1.45*
Tibia length	60	371.97	2.69	234	369.79	1.32	+2.18	+1.28	+1.13
Foot length	60	251.52	1.53	232	249.16	0.70	+2.36	+1.43	+1.67
Biacromial	61	387.46	2.14	233	383.70	1.24	+3.76	+1.29	+2.53
Chest width	61	277.97	2.05	233	279.60	1.31	−1.63	−3.42	+0.88
Chest depth	61	220.95	2.21	235	226.57	1.13	−5.62*	−7.15*	−1.34
Head length	61	188.08	0.82	235	188.45	0.43	−0.37	−0.92	−0.34
Head breadth	61	146.10	0.61	235	147.02	0.36	−0.92	−1.23	−0.69
Head height	61	127.11	0.78	235	128.11	0.34	−1.00	−1.31	−1.20
Minimum frontal	61	104.02	0.48	236	104.12	0.29	−0.10	−0.50	−0.67
Bizygomatic	61	136.84	0.66	235	136.96	0.34	−0.12	−0.54	+0.79
Bigonial	61	103.84	0.78	236	104.76	0.37	−0.92	−1.21	−0.12
Total facial hgt.	61	124.13	0.85	236	123.63	0.43	+0.50	−0.21	+0.31
Upper facial hgt.	60	74.50	0.63	211	74.14	0.31	+0.36	−0.02	+0.10
Lower facial hgt.	60	43.12	0.35	221	44.07	0.23	−0.95*	−1.14*	−0.68
Mouth width	61	56.85	0.54	233	56.68	0.26	+0.17	+0.18	+1.02
Interocular width	61	33.11	0.29	234	32.72	0.18	+0.39	+0.21	+0.58
Nose height	61	55.54	0.40	235	55.39	0.23	+0.15	−0.10	+0.41
Nose breadth	61	40.89	0.43	236	41.04	0.22	−0.15	−0.23	+0.77
Ear length	61	65.92	0.43	236	67.7	0.32	−1.85**	−1.97**	−0.20
Ear breadth	61	35.49	0.33	236	36.02	0.21	−0.53	−0.88*	+0.23

* Two to three times the standard error of the difference.

** Three or more times the standard error of the difference.

seemed possible that the differences between the migrants and non-migrants of 1948-1952 simply might be due to the fact that disproportionately large numbers of them were drawn from certain groups of previous migrants. Table 2 shows that previous migrational experience was a significant determinant of migration during the period 1948-1952.

TABLE 2

Male Migrants and Non-Migrants in 1948-1952 according to the Duration of their Previous Migration and to the Age at which they had first gone

MIGRATION PRIOR TO 1948 [1]	MIGRATION DURING 1948-1952				
	NEGATIVE		POSITIVE		TOTAL
	No.	%	No.	%	No.
I. Never	95	86	16	14	111
II. Before age 17 for 2 or more years	21	70	9	30	30
III. 17-27 for 2 or more years	51	77	15	23	66
IV. 15-27 for 1 year	18	60	12	40	30
V. 27 or over for 1 year	36	82	8	18	44
VI. 27 or over for 2 or more years	14	93	1	7	15

$\chi^2 = 12.1$

p with 5 degrees of freedom $< .05$

[1] One individual born in the United States is omitted.

Those who had previously been to the United States when 15 to 27 years old and who had returned to Mexico within 18 months were disproportionately numerous among the 1948-1952 migrants.

For each dimension the difference between the 1948-1952 migrant and non-migrant series was therefore weighted. This was done by taking separately the difference within each class of migrational experience. When these differences are multiplied by the proportion of 1948-1952 migrants in the respective subgroups, the sum is the mean difference weighted for past migration. As an approximate measure of the significance of these weighted differences one can use the standard errors derived from the unweighted means. This will tend to exaggerate the significance of differences, but as the hypothesis is that some of the differences between migrants and non-migrants may be ascribed to previous migrational history, the error will be in the direction of conservatism. As is shown in table 1, the difference in hand breadth between migrants and non-migrants during 1948-1952 is no longer significant.

However, the difference in ear breadth becomes significant. As the subgroups which average generally larger are over-represented among the 1948-1952 migrants, allowance for past migrational experience decreases differences in which the migrants are larger and increases differences in which they are smaller.

The selection for re-migration of returned migrants would be even more striking were it not for the fact that so small a percentage of the previous migrants falls in the age ranges within which labor migration is most frequent. Of 39 previous migrants under age 31 in 1948, 42% migrated again, whereas of 52 sedentes of that age only 27% went. Of 44 previous migrants aged 31–40 in 1948, 30% migrated as compared with only one (3.6%) of 28 sedentes. And of 112 previous migrants over 41 years old in 1948, 14.3% migrated again, whereas only one (3.2%) of 31 sedentes in this age group migrated.

Age is thus also an important factor in selection of migrants. As may be seen in table 3, a higher proportion of the 1948-1952 migrants are drawn from the younger adults measured in 1948.

TABLE 3

Male Migrants and Non-Migrants during 1948-1952 according to Age in 1948

	MIGRATION DURING 1948-1952				
	NEGATIVE		POSITIVE		TOTAL
AGE	No.	%	No.	%	No.
18–20	14	70	6	30	20
21–30	38	61	24	39	62
31–40 [1]	58	81	14	19	72
41–50	51	80	13	20	64
51–up	74	95	4	5	78

$\chi^2 = 25.0$
p with 4 degrees of freedom < 0.0001

[1] One individual born in the United States is omitted.

Many of the measurements under study are known to vary with age (Lasker, '53). If allowance is made for the changes in dimension with age, what can one say of differences between those who went to the United States after 1948 and those who did not? Age differences have been weighted in a manner exactly analogous to the way in which past migration was taken into account.

As may be seen in table 1, the age factor accounts for the significant differences in chest depth, lower facial height and ear height. Only the hand breadth difference remains unaccounted for by the change in age composition. Those who have unsuccessfully applied for contracts state that the agents of the United States Department of Agriculture, by whom they were interviewed concerning labor-contracts, inspect their hands. This was done, they say, to exclude those who seemed unaccustomed to hard manual work. One local story tells of a shopkeeper who dipped his hands in lime to harden them like a farmer's; the "Gringo," apparently detecting the ruse, told him that his hands were too rough and that he should go home and take a rest. Another anecdote tells of a barkeeper who was repeatedly refused a permit until he was accepted one day after he had cut and scratched his hands in a fall while drunk. It is interesting, therefore, that greater hand breadth—which might be selected for during these examinations—is the one measurement which is significantly larger in migrants even after allowance is made for age. But, as noted above, the difference in hand breadth is not significant when allowance is made for past migration. Furthermore, one might well expect at least one measurement to show this extent of difference just by chance.

In conclusion, there is little evidence of physical selection of migrants from Paracho to the United States even during a period when only a small proportion of those who want to work there are given labor contracts. When the total series is considered, or when allowance is made for the undoubted selection of those who have migrated before, a few minor differences may be statistically significant. But when the age distribution of those selected is taken into account, the mean differences in measured dimensions between this group of migrants and nonmigrants are adequately explained. There is selection for age and past migration, and probably for knowledge of English, past occupation, and industrial skills. There is also an economic selection at least to the extent of means to reach the community where the contracts are made, and frequently to pay bribes to get an interview with the proper authorities. With adequate means to do so, a few men who had been rejected were able to go to the United States on their own (either legally or as "wetbacks"). These factors so override in importance whatever considerations of physique might otherwise influence the choice of workers by the United States agents that—with possibly the single exception of hand breadth—no evidence of physical selection was found.

This conclusion is derived, however, from data concerning a single small community—a community peculiar in that migration to the United States is a common expectation of young men. It remains a question to what extent the widely held notion of physical selection of migrants may hold for other groups, but among at least some groups of labor migrants, such selection is evidently insignificant.

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FAT PATTERNING AND FAT INTERCORRELATIONS IN THE ADULT MALE

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INTRODUCTION

THE investigation of subcutaneous fat has at least two somewhat divergent objectives. The first objective is descriptive: to establish the patterning and changes in subcutaneous fat, differences in thickness throughout the body from infancy through advancing age. The second objective is to determine the interrelationship among the different fat thicknesses measured, and the relationship between subcutaneous fat and the total body fat.

Information on subcutaneous fat thickness is most abundant for children, where fat-caliper measurements have been supplemented by teleoroentgenography since 1939. Data on fat thickness intercorrelations in childhood are also available for three age levels (Reynolds '51). Information on adults, however, is more limited. With the exception of leg fat (Reynolds and Grote '48, Reynolds '48, '51, and Garn and Saalberg '52) contemporary adult data is almost entirely based on skin-fold measurements. Since the skin-fold technique is difficult to execute on certain areas of the body, and the x-ray method affords a more precise localization of fat-thickness measurements, further data on patterning and intercorrelations are to be desired especially on adults.

It is the purpose of this paper to provide data on the patterning of subcutaneous fat in the adult male, and to explore the intercorrelations among the different regions. It is the further purpose of this paper to discover which sections of the *tela adiposa* are more indicative of body fat in general, and to determine the relationship between fat thickness and weight.

METHODS AND MATERIALS

The present study is based on soft-tissue teleoroentgenograms of 87 healthy white males, ranging from 20–69 years of age. With one

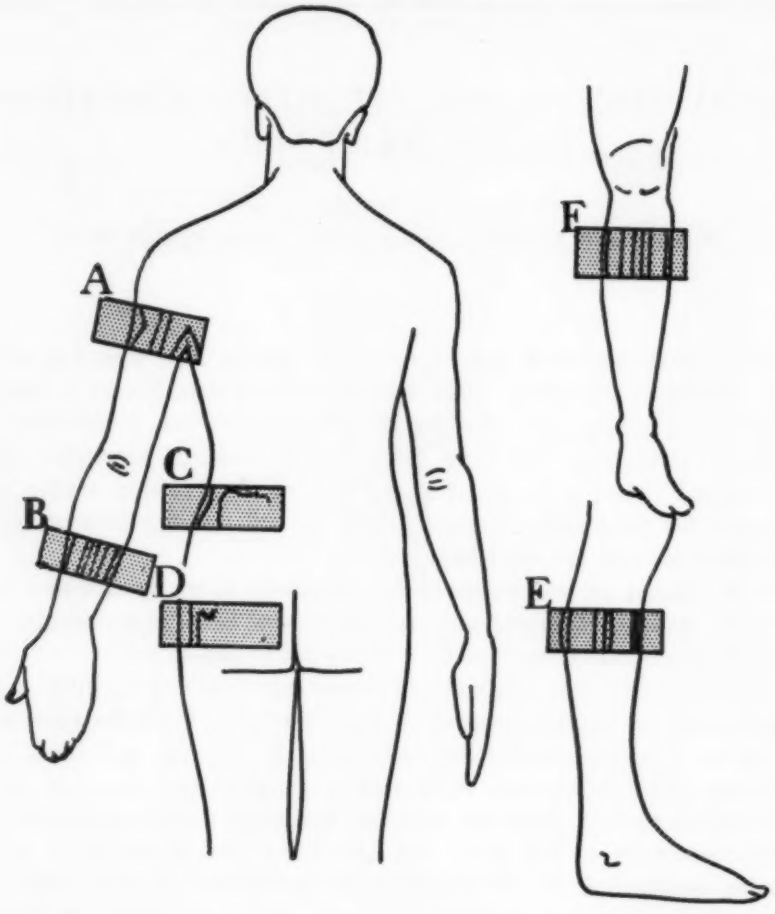

FIG. 1. Location of X-ray "sections" described in the text: A. deltoid insertion section; B. lower arm section; C. iliac section; D. trochanteric section; E. antero-posterior leg section (lateral view); F. transverse leg section (A-P view).

exception all were regular participants in the Fels study, being for the most part parents of children enrolled in the longitudinal program.

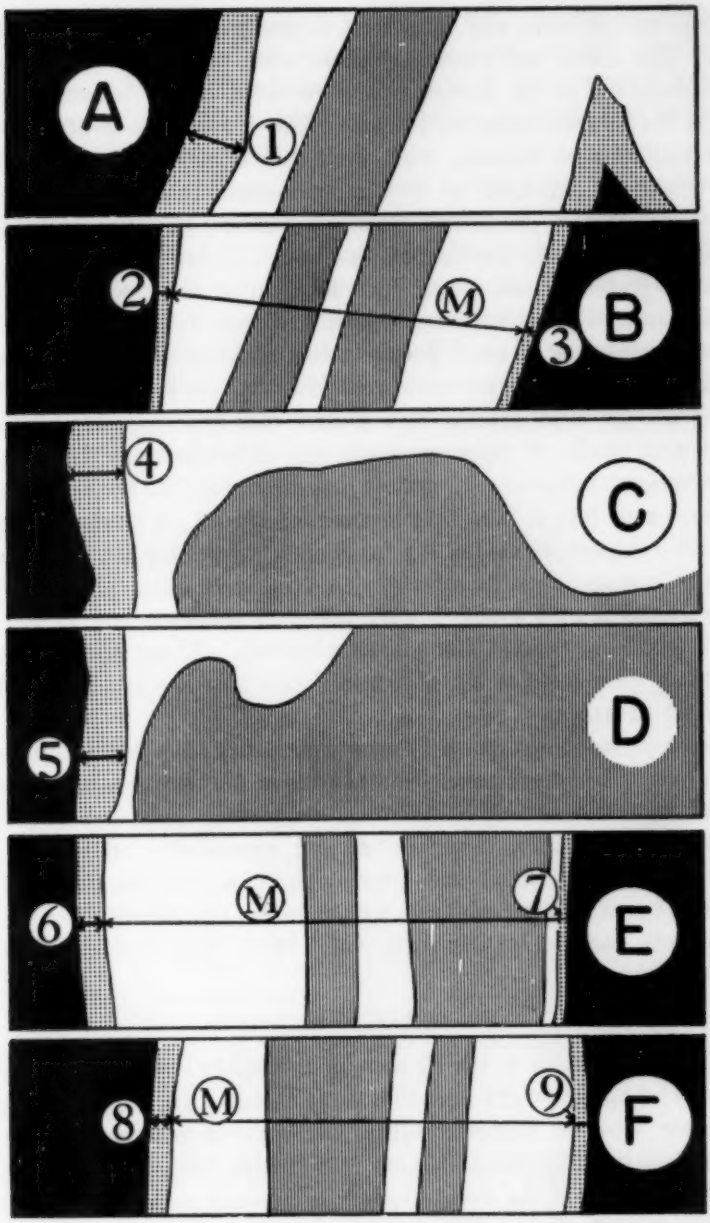

FIG. 2. Tracing of an X-ray series showing fat thicknesses measured in this study: M. level of maximum muscle diameter; 1. deltoid insertion; 2. lateral arm; 3. medial arm; 4. iliac; 5. trochanteric; 6. posterior leg; 7. anterior leg; 8. medial leg; 9. lateral leg. Sections lettered as in Fig. 1.

All were native born, and most were lifelong residents of southwestern Ohio. One active but extremely obese man, weighing 307 pounds, is not represented in the means, but is included in the intercorrelations.

The x-rays were taken at a standardized 6 foot tube-to-film distance, at 14 milliampere seconds, with peak kilovoltages appropriate to the part thickness. A total of 6 x-ray "sections" were taken of each subject, as follows: A. deltoid insertion section; B. lower arm section; C. iliac section; D. trochanteric section; E. lateral calf view, and F. antero-posterior calf view. The location of these sections, as well as the standard poses used are shown in figure 1.

Fat thicknesses, or more precisely the thickness of the skin plus the fat-containing tissue were measured directly on the x-rays, using a vernier caliper with ground tips (Garn and Saalberg '53); measurements were made at right angles to the skin surface. The nine fat measurements included: 1. deltoid insertion fat; 2. medial arm fat; 3. lateral arm fat; 4. iliac fat; 5. trochanteric fat; 6. posterior leg fat; 7. anterior leg fat; 8. medial leg fat; and 9. lateral leg fat. Thicknesses 1, 4 and 5 were taken in reference to fixed anatomical points. Thicknesses 2 and 3, and 6 and 9 were taken at mid-arm and at the level of the maximum muscle diameter respectively. These measured thicknesses and their location are shown in figure 2, which is a tracing of an actual set of x-rays.

Two sources of error may be mentioned, magnification (angular distortion) and tissue hydration. Since the focal film distance was constant, magnification is reasonably consistent within each body area considered. The systematic errors, therefore, do not appreciably affect the mean values and do not affect the intercorrelations. Errors due to tissue hydration were minimized both by confining the data collection to a three month period (May to early July, 1953), and through the use of air conditioning.

FINDINGS

As shown in table 1, the 87 men in this study averaged 176.6 cm in stature, 76.4 kg in weight and 40.8 years in age. In height and weight they come close to reported values for men of comparable age and economic status (Brožek and Keys '51, Brožek '52).

The thickness of the subcutaneous fat deposits measured here, varied from an average of 18.9 mm over the iliac crest to 2.7 mm (including skin) over the tibia. The thickest fat layers measured were located over the pelvis and at the deltoid insertion, the thinnest on the medial

aspect of the forearm, and on the anterior leg. Ranked in descending order of thickness, the fat sequence was iliac, deltoid, trochanteric, posterior leg, medial leg, lateral leg, lateral arm, medial arm, and anterior leg. Iliac fat, in addition to being thickest, also showed the greatest absolute variability.

While the ranking given above, based on the mean thicknesses, provides an idea of the relative fat thickness at the 9 sites measured, it was not the modal sequence. In some individuals deltoid fat was the thickest, in others iliac fat. Fat rankings were closely related to the total amount of fat, and to total body weight. Thus, in individuals weighing under 74 kg, deltoid fat exceeded other thicknesses, while at 75 kg and above, iliac fat was the thickest (table 1). This shift in thickness rankings was also evident in comparing younger and lighter subjects to older and heavier subjects.

TABLE 1

Body Size, Fat Thicknesses, and Fat Rankings

MEASUREMENT	NO.	MEAN	S. D.	C. V.	FAT RANKING	RANKING LIGHTER MEN [1]	RANKING HEAVIER MEN [2]
Age (yrs)	87	40.8	11.1	27.2			
Height (cm)	86	176.6 ± 0.5	4.9	2.8			
Weight (kg)	87	76.4 ± 1.0	9.1	11.9			
Deltoid fat (mm)	86	17.8 ± 0.5	4.5	25.3	2	1	2
Lateral arm fat	86	4.6 ± 0.2	1.7	36.9	7	7	7
Medial arm fat	86	3.5 ± 0.1	1.3	37.1	8	8	8
Iliac fat	83	18.9 ± 0.9	8.3	43.9	1	2	1
Trochanteric fat	82	16.6 ± 0.8	6.9	41.5	3	3	3
Posterior leg fat	84	7.2 ± 0.3	2.5	34.7	4	4	4
Anterior leg fat	81	2.7 ± 0.1	0.7	25.9	9	9	9
Medial leg fat	84	6.3 ± 0.3	2.4	38.1	5	5	5
Lateral leg fat	84	4.7 ± 0.2	1.6	34.8	6	6	6

1. Men weighing between 50 and 74 kg.
2. Men weighing between 75 and 100 kg.

All of the 9 fat thicknesses were positively and significantly intercorrelated, with values of r ranging from 0.33 to 0.79 as shown in table 2. The regression lines were prevailingly linear, thus indicating that r rather than η was the appropriate measure of covariance. How-

TABLE 2

Intercorrelations among Fat Layers

MEASUREMENT	1. DELTOID	2. LATERAL ARM	3. MEDIAL ARM	4. ILIAC	5. TROCHANTER	6. POSTERIOR LEG	7. ANTERIOR LEG	8. MEDIAL LEG	9. LATERAL LEG	10. WEIGHT
1. Deltoid Insertion	—	.67	.54	.74	.75	.44	.50	.62	.56	.67
2. Lateral Arm	.67	—	.68	.62	.68	.37	.56	.59	.50	.62
3. Medial Arm	.54	.68	—	.48	.65	.38	.52	.70	.40	.21
4. Iliac	.74	.62	.48	—	.75	.33	.46	.50	.44	.63
5. Trochanter	.75	.68	.65	.75	—	.44	.68	.79	.61	.71
6. Posterior Leg	.44	.37	.38	.33	.44	—	.43	.56	.53	.41
7. Anterior Leg	.50	.56	.52	.46	.68	.43	—	.79	.62	.61
8. Medial Leg	.62	.59	.70	.50	.79	.56	.79	—	.51	.71
9. Lateral Leg	.56	.50	.40	.44	.61	.53	.62	.51	—	.29
10. Weight	.67	.62	.21	.63	.71	.41	.61	.71	.29	—

ever, as shown in table 2, trochanteric fat, medial leg fat, and deltoid fat generally exhibited higher intercorrelations with the various fat thicknesses, than did lateral arm fat, lateral leg fat and especially posterior leg fat.

In order to obtain a more acceptable index of the relationship between any one fat measurement and the remaining 8, than could be obtained from the mean r, the values in table 2 were transformed into z values (the z transform of r), using table V-B in Fisher ('48). The z values, for each thickness, were then averaged, as shown in table 3.

TABLE 3

Rankings of Predictive Efficiency and Relative Variability for 9 Fat Thicknesses

FAT THICKNESS	MEAN Z [1]	Z RANKING	C. V.[2]	VARIABILITY RANKING
1. Deltoid Insertion	.60	3	25.3	9
2. Lateral Arm	.54	7	36.9	5
3. Medial Arm	.58	4	37.1	4
4. Iliac	.54	6	43.9	1
5. Trochanteric	.67	1	41.5	2
6. Posterior Leg	.44	9	34.7	7
7. Anterior Leg	.57	5	25.9	8
8. Medial Leg	.63	2	38.1	3
9. Lateral Leg	.52	8	34.8	6

[1] From data in table 2 and table V-B in Fisher ('48).
[2] From table 1.

It is evident, in this table, that tronchanteric fat and medial leg fat are more highly covariant with the other layers, while lateral and posterior leg fat have less in common with the other fat measurements.

The question arose as to whether the predictive efficiency of a fat layer is related to its average thickness. Accordingly thickness rankings (from table 2) were correlated with mean z rankings (from table 3) using Spearman's ρ formula (Edwards '49). The obtained ρ of 0.22 could not be considered significantly different from zero. It is not likely, therefore, that thickness, per se, is indicative of the degree of communality exhibited by a given fat deposit. Nor does the location of the fat enter, as is evident in table 3. The three "best" predictors of fat thickness in general are widely separated in anatomical space, while the second best and the poorest are but centimeters apart.

Finally, an attempt to discover a relationship between predictive efficiency and relative variability of the different fat measurements was no more successful, the obtained ρ being 0.23.

It is of interest to note that trochanteric and medial leg fat exhibit the highest correlations with gross weight ($r = 0.71$) while the remaining fat measurement lag behind, just as they did in the mean z values. These correlations serve to show that fat, while not the only determinant of weight, accounts for much of the interpersonal variance, up to 50% in the age group considered, and they suggest that the fat weight, as distinguished from the total body weight, may be estimated from trochanteric or medial leg fat measurements using the ordinary regression equations.

DISCUSSION

It is evident, from the findings reported here, that the thickness of the *tela adiposa* varies both between anatomical regions, and within such regions. In the adult male, the fat deposits over the pelvic region are the broadest, averaging 4 times as thick as the fat on the lower arm, and 6 times the thickness of the fat over the tibia. But on the lower leg (to take just one anatomical region) the fat layer is far from uniform. Medial leg fat is consistently thicker than lateral leg fat, and the fat on the back of the leg averages more than twice as thick as the fat on the front. And, as the total amount of fat increases, there is an alteration in the relative thickness of some of the fat layers. Thus in leaner males, deltoid insertion fat is the thickest single deposit, while in males over 75 kg in weight, iliac fat exceeds all other thicknesses.

As might be expected, all 9 fat thicknesses measured here are positively and significantly intercorrelated, with values of r ranging from 0.33 to 0.79. However, some of the fatty deposits exhibit a higher general covariance than others. Trochanteric fat shows both the highest correlation with weight (0.71) and the highest mean z (0.67); medial leg fat and deltoid fat also tend to vary directly with the other fat thicknesses, and to be moderately correlated with gross weight. Posterior leg fat exhibits the least tendency toward group covariance. Evidently absolute fat thickness is no indication of the predictive efficiency of a given fat measurement, nor in fact is location. Medial leg fat, though a notably good index of general fat thickness, is far from being the thickest deposit, and is situated in proximity to the poorest predictors of fat in general. At present, therefore, no general rule for predetermining the most representative fat deposit can be formulated.

Comparing the intercorrelations obtained here, with others given in the literature, the values appear to be reasonably similar. Of the three age groups investigated by Reynolds ('51) the intercorrelations obtained on these 87 adult males are comparable to his 7 and 11 year olds, but are lower than those for his 15 year old boys. While Brožek and Keys ('51) measured different fat thicknesses and used a different technique (skin-folds) it is interesting to see that their intercorrelations were of the same magnitude for males of comparable age, but markedly higher for younger males (mean age 21). There is a suggestion, therefore, that subcutaneous fat varies as a unit near the time of peak androgen production, while at other ages local autonomies exert a greater influence.

From the standpoint of nutritional anthropometry, it would seem that the simple bitrochanteric diameter, taken as a "contact" measurement might satisfactorily meter fluctuations in body fat. Trochanteric fat, it is seen, correlates well with gross weight, it intercorrelates well with other fat thicknesses, and the total range of thickness is large. At the same time since the traditional bi-iliac measurement includes an average of 4 cm of fat in this age group, one would hesitate to accept it as an approximation to the true skeletal dimension.

If a single fat measurement, as determined from soft-tissue x-rays, is desired for nutritional or physiological research, preference would obviously be extended to trochanteric fat or to medial leg fat. Both are representative of fat in general, and both vary directly with weight. Technically, the antero-posterior leg view is the simpler, and the least inconvenient to the subject. Brožek, it may be recalled, doubted the use of the calf section, writing that "biologically it seems to be a questionable indicator of the general level of fat content" (Brožek '53, p. 157). While this is true of posterior leg fat, it is by no means true of medial leg fat. In all likelihood Brožek made this pessimistic prediction in the absence of data on fat intercorrelations.

While the present study stresses the way the subcutaneous fat layer behaves as a unit, despite regional differences in absolute thickness, this is but part of the total picture. The *tela adiposa* is a single sheet, its volume is related to the volume of the inner fat, and it is possible to estimate the fat weight or percentage of fat of an individual from a given measured thickness. At the same time there are marked interpersonal differences not just in the amount of fat, but in the way fat is distributed. One man may be fat, but with less fat on his legs than would be predicted from his absolute fat content. Another may have

little fat, but with more on his legs than might be expected. The extent of such individual deviations from their own baseline (or mean *z* score) is a problem in its own right, and one that cannot be approached through the calculations of the weight of fat, or the percentage fat. Hence the need for regional fat measurements, as well as measurements or estimates of the total body fat.

SUMMARY

1. Patterning and intercorrelations in subcutaneous fat thickness were investigated, through the use of teleoroentgenograms, on 87 active white males aged 20–69 years.

2. Mean fat thickness ranged from 18.9 mm (iliac fat) to 2.7 mm (anterior leg fat). Mean thickness rankings were (in decreasing order) iliac fat, deltoid fat, trochanteric fat, posterior leg fat, medial leg fat, lateral arm fat, lateral leg fat, medial arm fat and anterior leg fat.

3. Absolute thickness rankings changed with increasing weight, thus deltoid-iliac-trochanteric was characteristic of leaner men, and iliac-deltoid-trochanteric was more common among fatter men.

4. Intercorrelations among the 9 fat thickness ranged from 0.33 to 0.79.

5. Trochanteric and medial leg fat showed the highest intercorrelations, and correlated well with gross weight, while lateral and posterior leg fat exhibited a greater degree of autonomy.

6. Neither mean thickness nor anatomical location provided a guide to the predictive efficiency of a fat layer.

7. Attention was drawn to the distinction between studies relating to the total fat volume and those concerned with individual differences in the patterns of fat deposition.

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